GROWTH AND YIELD
MASTER PLAN FOR CENTRAL REGION

"Monitoring and Modelling Ontario's Forests"

Central Region Science & Technology
Technical Report # 40

Ontario

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Murray E. Woods

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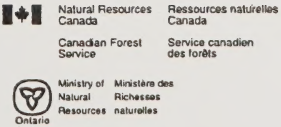

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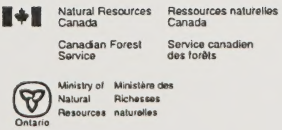

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Executive Summary

The Ontario Ministry of Natural Resources recognizes that sustainable forest management for a variety of values, including timber, aesthetics, maintenance of biodiversity, fish and wildlife species and their habitat, maintenance of traditional lifestyles, recreation and environmental protection, can be greatly assisted in the short and long term by improved forest growth and productivity information.

Funding under the Sustainable Forestry Program has permitted the development of an integrated and comprehensive provincial program that has focussed on providing resource management answers at different spatial levels. The plot design allows multi-use by other resource programs interested in gathering additional information on other ecosystem attributes.

The Central Region growth and yield master plan provides strategic and tactical direction for growth and yield (G&Y) activities within Central Region. These activities include the stratification of the region for sampling efficiency, data collection standards and model development. The program is structured to sample and monitor long-term tree and stand dynamics in managed and un-managed stand conditions. This information will be used to develop the tools required to manage Central Region's diverse forest types in a sustainable manner.

The Central Region G&Y program has the advantage of building on various sets of historical G&Y efforts. These efforts were local-needs driven projects that provided critical answers to their objectives. In many cases, these small plot networks can be incorporated into the larger regional and provincial network. If not suitable, they provide excellent sources of validation data sets. In order to provide earlier short-term products the use of these data sets in the regional program is a high priority.

The goals of the G&Y program are:

- to provide comprehensive information on the G&Y of Ontario's forest stands;
- to provide consistent, reliable and scientifically sound forest G&Y data;
- to develop a stratification system for sampling forest cover type priorities;
- to provide a network of permanent sample plots (PSP's) for forest cover types that provide for long-term forest monitoring;
- to develop and transfer tools and models for timber and other forest values (habitat, etc.) management in a timely manner.

The objectives of the G&Y program have been categorized into short, medium and long term.

Short Term Objectives (1-3 years)

- refine and test the stratification system used in the program;
- refine and test minimum standards for establishment of PSP's;
- develop and complete regional G&Y Master Plan;
- commence establishment of a chronosequence PSP network;
- review and evaluate existing G&Y datasets;
- assess existing G&Y models for applicability to Ontario;
- design a Provincial/Regional database for collected G&Y data;
- provide summary factsheets of established PSP's;

Medium Term Objectives (3-5 years)

- develop preliminary G&Y models from available data for input into forest level wood and habitat supply analyses.
- complete the establishment of the PSP network including initial plot measurements and retrospective measures from increment cores and stem analyses.

Long Term Objectives (5-30 years)

- develop operational growth models validated with local PSP data to be used in forest level management decisions (including habitat supply components);
- develop predictive models for the evaluation of treatment responses which account for site characteristics and a variety of silvicultural treatment regimes;
- provide G&Y prediction tools for stands undergoing natural disturbance, from biotic and abiotic factors (e.g. fire, insects) through increased understanding of the processes involved in stand dynamics;
- provide field practitioners with practical tools and methods for relating site (Central Ontario Forest Ecosystem Classification) and productivity;
- provide stand development and succession information to forest managers in support of integrated resource management decision making
- remeasure and maintain PSP network including replacement and treatments.

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1.0 Introduction

Today's resource managers require more information on the forest resource than ever before. In the past, management decisions could only be based only on an estimate of timber yield. The public of the 1990's have demanded that much more be considered prior to man's intervention in nature's domain. All actions have potential impact on the sustainability of the forest resource.

The Ontario Ministry of Natural Resources (OMNR) recognizes that sustainable forest management for a variety of values, including timber, aesthetics, maintenance of biodiversity, fish and wildlife species and their habitat, maintenance of traditional lifestyles, recreation and environmental protection, can be greatly assisted in the short and long term by improved forest growth and productivity information (OMNR 1992).

The Central Region growth and yield master plan is intended to provide strategic and tactical direction for growth and yield (G&Y) activities within Central Region and document the linkages to many groups within and outside of the OMNR. These activities include the stratification of the region for sampling efficiency, data collection standards and model development.

Program linkages include:

- the role of the regional G&Y program within the Provincial program;
- the role of the regional G&Y program with other Central Region initiatives and programs;
- the role of the regional G&Y program and other regional (Northwest, Northeast, Southern) programs.

2.0 Physical Description of the Central Region

2.1 Geographical Position

The Central Region of the OMNR has an irregular shape and lies roughly between 44° 45' and 47° 30' latitude. It is bounded in the west by Lake Superior and extends inland and eastward along the north shore of Georgian Bay to the Ottawa River Valley and the Ontario/Quebec Provincial boundary. The region encompasses a total area of approximately 110,000 km^2 (Pinto et al. 1991). Administratively the Region is divided into 8 Districts: Sault Ste. Marie, Sudbury, North Bay, Temagami, Parry Sound, Bancroft, Algonquin Park and Pembroke (Figure 1).

2.2 Landbase Statistics

As described in The Timber Resources of Ontario - 1993 (OMNR, 1993), Central Region

Figure 1. The Central Region of the Ontario Ministry of Natural Resources.

encompasses over 11 million hectares of land and water. Seventy-five percent of the area is forested land, 8% is non-forested, and the remaining 17.4% is water (Table 1). 66% of the forested land is Productive Forest area. Crown Land makes up 47%, Private Land 19% and Federal land 0.1%. Thirty-five percent of the Productive Forest area is coniferous, 36% tolerant hardwood and 29% intolerant hardwood species (Table 2). The coniferous forest types provide 35% of the volume, tolerant hardwoods 37% and intolerant hardwoods 28 % (Table 3).

2.3 Ecoregions of the Central Region

Delineation of the Province of Ontario into ecologically different units was pioneered by Angus Hills in 1959. This work has been refined and calibrated through the years by various people.

In an attempt to align Ontario's ecological land classification system(s) with other provinces, Wickware and Rubec (1989b) developed an integrated approach of utilizing existing Provincial ecological databases of different scales and linking them. This has allowed maps to be produced with boundaries corresponding to its neighbouring province, and similar attributes grouped.

Terrestrial ecoregions and ecodistricts boundaries are coincident with soil landscape polygon boundaries throughout the province (Wickware and Rubec 1989a). There are similarities between the ecoregion - site region and ecodistrict - site district boundaries of those of Hills (1976) but they are not coincident.

The ecodistricts of the Wickware and Rubec (1989a) system represent a pattern of hydrology (lakes and rivers), geology (lineaments), landforms, vegetation, land use and topography. Ecoregions are best characterized as land which has "distinctive ecological response to climate as expressed by the development of vegetation, soils, water, and fauna" (Rubec and Wiken 1983).

A total of 17 ecoregions have been characterized for the province of Ontario (Figure 2). These ecoregions have been further subdivided into 79 ecodistricts.

Central Region comprises 3 ecoregions: Nipissing, Chapleau Plains and Saint Laurent; with Nipissing representing the largest portion of the region. A total of 9 ecodistricts (in whole or in part) are identified within the ecoregions making up the administrative boundaries of Central Region. The 9 ecodistricts are numbered: 14, 15, 16, 17, 18, a portion on 19, a portion of 20, a portion of 22 and a portion of 24.

The climate, terrain, soil and vegetation characterizations for the 3 ecoregions within the Central Region, as documented by Wickware and Rubec (1989a), are presented below.

Ownership	Non-Forested Land	Non-Productive Forest	Productive Forest	All Land Sub-total	Water	Total
Crown Land	44,550	667,994	4,407,774	5,120,318	1,878,553	6,998,871
Recreational Reserves	1,197	16,649	135,418	153,264	476	153,740
Provincial Parks	3,732	62,894	760,633	827,259	65,914	893,173
Crown Sub-total	**49,479**	**747,537**	**5,303,825**	**6,100,841**	**1,944,943**	**8,045,784**
Private Land	647,684	254,379	2,145,163	3,047,226	549	3,047,775
Agreement Forest	495	2,629	15,858	18,982	0	18,982
Private Sub-total	**648,179**	**257,008**	**2,161,021**	**3,066,208**	**549**	**3,066,757**
Indian Reserves	648,179	257,008	20,401	135,417	1,115	136,532
Other Federal	60,958	282	415	61,655	24,128	85,783
Federal Sub-total	**175,116**	**1,140**	**20,816**	**197,072**	**25,243**	**222,315**
Total Inventoried	**872,774**	**1,005,685**	**7,485,662**	**9,364,121**	**1,970,735**	**11,334,856**
Areas by Percentage						
Crown Sub-total	0.4%	6.6%	46.8%	53.8%	17.2%	71.0%
Private Sub-total	5.7%	2.2%	18.9%	26.9%	0.0%	26.9%
Federal Sub-total	0.0%	0.0%	0.1%	0.2%	0.0%	0.2%
Grand Total	**7.7%**	**8.9%**	**66.0%**	**82.6%**	**17.4%**	**100.0%**

Source - The Timber Resources of Ontario - 1993

Table 1. Major Land Classifications of the Central Region Covered by the Forest Resources Inventory (Area in hectares).

Species	B&S NSR	0 - 20 yrs	20 - 40 yrs	40 - 60 yrs	60 - 80 yrs	80 - 100 yrs	100 - 120 yrs	120+ yrs	Total
White Pine	41,135	8,130	8,146	29,556	124,864	177,571	43,426	65,394	498,222
Red Pine	11,041	20,412	8,208	7,865	18,485	19,358	4,679	7,628	97,676
Jack Pine	36,296	19,203	104,479	89,600	103,026	55,882	17,141	4,263	429,890
Spruce	43,038	16,303	16,402	63,024	126,828	121,408	64,915	35,870	487,788
Balsam Fir	15,797	23,616	26,148	109,963	122,602	44,796	7,958	2,492	353,372
Other Conifers	31,568	1,311	2,708	32,198	80,313	56,805	38,340	60,277	303,520
Softwood Sub-total	178,875	88,975	166,091	332,206	576,118	475,820	176,459	175,924	2,170,468
Hemlock	396	43	223	2,608	7,964	12,196	11,226	62,116	96,772
Hard Maple	51,726	37,160	43,061	251,076	287,877	273,741	253,064	607,321	1,805,026
Yellow Birch	1,503	693	426	2,072	4,897	9,328	11,553	112,884	143,356
Other Tolerant Hardwoods	14,831	6,851	9,693	75,879	139,777	84,627	34,407	25,758	391,823
Tolerant Hardwood Sub-total	68,456	44,747	53,403	331,635	440,515	379,892	310,250	808,079	2,436,977
Poplar	64,111	27,648	89,564	398,828	342,800	94,895	16,182	1,928	1,035,956
White Birch	50,310	20,021	81,249	311,075	278,497	102,516	26,197	13,555	883,420
Intolerant Hardwood Sub-total	114,421	47,669	170,813	709,903	621,297	197,411	42,379	15,483	1,919,376
Grand Total	**361,752**	**181,391**	**390,307**	**1,373,744**	**1,637,930**	**1,053,123**	**529,088**	**999,486**	**6,526,821**

Source - The Timber Resources of Ontario - 1993

Table 2. **Area of the Regular Production Forest of the Central Region by Species and Age Class (All Ownerships) (Areas in hectares)**

Species	B&S NSR	0 - 20 yrs	20 - 40 yrs	40 - 60 yrs	60 - 80 yrs	80 - 100 yrs	100 - 120 yrs	120+ yrs	Total
White Pine	-	38,036	828,710	4,752,203	24,639,733	35,970,978	9,776,336	16,379,607	92,385,603
Red Pine	-	303,656	1,059,763	1,347,746	4,090,534	4,495,279	1,185,966	1,990,560	14,473,504
Jack Pine	-	528,012	9,482,966	13,814,441	16,614,388	9,869,204	2,631,917	639,597	53,580,525
Spruce	-	43,015	1,075,442	8,175,507	18,679,366	19,215,310	10,276,330	5,707,893	63,172,863
Balsam Fir	-	33,606	2,291,442	15,759,907	20,281,420	7,217,564	1,284,991	367,662	47,236,592
Other Conifers	-	2,442	231,794	3,413,322	10,530,273	8,116,688	5,617,789	8,743,063	36,655,371
Softwood Sub-total	-	948,767	14,970,117	47,263,126	94,835,714	84,885,023	30,773,329	33,828,382	307,504,458
Hemlock	-	672	19,901	304,685	1,191,388	2,079,697	1,976,250	12,170,287	17,742,880
Hard Maple	-	93,785	2,976,685	27,898,084	40,695,499	43,550,042	44,621,690	115,845,138	275,680,923
Yellow Birch	-	914	13,740	163,849	621,755	1,200,031	1,741,083	19,147,807	22,889,179
Other Tolerant Hardwoods	-	13,361	571,363	7,809,825	17,117,350	11,960,143	5,502,600	4,623,752	47,598,394
Tolerant Hardwood Sub-total	-	108,732	3,581,689	36,176,443	59,625,992	58,789,913	53,841,623	151,786,984	363,911,376
Poplar	-	427,844	8,385,163	63,078,402	64,784,171	20,127,567	3,500,846	443,511	160,747,504
White Birch	-	292,427	5,524,217	36,265,273	34,408,885	13,625,241	3,218,892	1,776,113	95,111,048
Intolerant Hardwood Sub-total	-	720,271	13,909,380	99,343,675	99,193,056	33,752,808	6,719,738	2,219,624	255,858,552
Grand Total	-	**1,777,770**	**32,461,186**	**182,783,244**	**253,654,762**	**177,427,744**	**91,334,690**	**187,834,990**	**927,274,386**

Source - The Timber Resources of Ontario - 1993

Table 3. **Volume of the Regular Production Forest of the Central Region by Species and Age Class (All Ownerships) (Volume in cubic metres)**

Figure 2. Ecoregions of Ontario.

2.3.1 Nipissing Ecoregion

The climate of the Nipissing ecoregion has been summarized by Wickware and Rubec (1989a) as "warm summers with mean daily temperatures extending above-freezing occurring from late March to December. Winters are cold and snowy with total snowfall varying across the ecoregion. Mean annual temperatures vary across the ecoregion, from 3.9° Celsius (C) in the Algonquin Park area to 4.8° C in the Sudbury area. Maximum rainfall occurs during the month of September when approximately 100 mm falls. Total rainfall across the ecoregion averages 620 mm."

The terrain of the Nipissing ecoregion is dominated by a moderately broken to strongly broken morainal plain with shallow sandy loam over bedrock. The terrain (along Lake Huron) is weakly to moderately broken morainal plain with very shallow to bedrock soils. Along the north channel of Lake Huron, the terrain is characteristically moderately broken to weakly broken morainal plain, with sandy-loamy-clayey lacustrian deposits occurring in the lower lying areas.

Soil types vary from Humo-Ferric Podzols with grey Brown Luvisols on dry, well drained sites to Melanic Brunisols on the fresh, well to moderately well drained sites. Gleysols are found on the imperfectly drained sites with Organic soils found in poorly drained depressions.

The vegetation characterizing the Nipissing ecoregion consists of tolerant hardwoods including sugar maple (Acer saccharum Marsh.), yellow birch (Betula alleghaniensis Britton), eastern hemlock (Tsuga canadensis L. Carr.) and eastern white pine (Pinus strobus L.) on fresh to well drained sites. Species such as red pine (Pinus resinosa Ait.), eastern white pine and red oak (Quercus rubra L.) are found in the dry, rapidly drained sites. Wetter, imperfectly drained sites support black ash (Fraxinus nigra Marsh.), red maple (Acer rubrum L.), white spruce (Picea glauca (Moench) Voss), tamarack (Larix laricina (Du Roi) k. Koch) and eastern white cedar (Thuja occidentalis L.).

2.3.2 Chapleau Plains Ecoregion

The climate of the entire Chapleau Plains ecoregion is characterized by warm summers and cold winters. Monthly precipitation levels for the Ecoregion range from 35 to 65 mm with maximums being reached in the summer months. Lake Superior shore portions of the ecoregion (ecodistrict 24) receives, on average, higher precipitation than the more inland portions. The mean annual temperature of the western portion (data from the Chapleau area) of the ecoregion is 2.2° C.

The terrain of the ecoregion is characterized by strongly broken to moderately broken topography along the shore sections of Lake Superior. Within the eastern and central sections it is characterized by more moderately to weakly broken topography. Parent materials are sandy to loamy in the western Lake Superior shore sections, with bedrock exposures and bedrock cliffs occurring frequently. Within the Central section of the ecoregion, parent materials of sandy loam to loamy soils are found often in shallow to bedrock situations.

The soils along the Lake Superior Shore sections and the Central sections of the ecoregion are typically Humo-Ferric Podzols that have developed either under a hardwood or Boreal forest canopy. The eastern portion of the ecoregion is dominated by sites with well drained clay deposits containing Brunisolic Grey Luvisols and Grey Luvisols. Gleysolic and Organic soils occupy imperfectly and poorly drained sites throughout the ecoregion.

The vegetation characterizing the fresh well drained sites of Lake Superior Shore sections of the ecoregion are tolerant hardwoods such as sugar maple, red maple and yellow birch. The poorly drained sections within the Lake Superior shore sections are characterized by black spruce (Picea mariana (Mill.) B. S. P.), tamarack and eastern white cedar. Within the eastern sections of the ecoregion, the dry and rapidly drained sites are inhabited by jack pine (Pinus banksiana Lamb) and black spruce. In addition, aggregations of the vegetation throughout the ecoregion result in mixedwood conditions.

2.3.3 Saint Laurent Ecoregion

The climate of the Saint-Laurent Ecoregion is characterized by warm summers and cold, snowy winters with monthly precipitation averaging 75 to 80 mm. Little variation in levels of precipitation and timing occurs across the ecoregion. Total mean annual precipitation ranges from 875 to 925 mm, with annual average temperatures of 5.7 ° C to 6.6° C.

The terrain on the northern portion of the ecoregion is dominated by weakly broken to very weakly broken plains of sand or poorly drained clay in the Ottawa Valley area. These deposits are a result of the post glacial Champlain Sea.

The poorly drained clay soils of the ecoregion are generally Grey Brown Luvisols or Luvic Gleysols. Typical Melanic Brunisols or Humo-Ferric Podzols develop on coarser textured loamy materials. Organic soils occur frequently throughout the ecoregion in areas of poorly drained clay plains or depressions in morainal deposits.

The vegetation characterizing the fresh, well drained sites of the ecoregion includes: sugar maple, oak, beech and eastern hemlock. Species such as white elm, ash, red maple and eastern white cedar occur on shallow, imperfectly drained peat deposits. Drier sites are typically characterized by white pine, red pine and red oak.

3.0 Growth and Yield Program Framework

Ontario's Provincial Government has embraced the term *Sustainable Development* in the setting of programs and policies. The need for more information on *"ecosystem function"* is necessary if we are to participate and manage the resources within a sustainable forestry context.

Sustainable Forestry ensures long term health of forest ecosystems, contributes to global environmental benefits, and provides an array of social, cultural and economic opportunities. The forest is managed for many diverse values including wildlife, fisheries, tourism, outdoor recreation and timber.

3.1 History

G&Y activities in the province date back to the 1920's. Numerous company and government (Provincial and Federal) research efforts were undertaken. Unfortunately, few commonalties exist in terms of scientific approaches or data standards that would allow for aggregation of the data. A more comprehensive list of G&Y efforts can be found in the Provincial G&Y master plan (OMNR 1992).

Central Region has had local G&Y projects directed at fulfilling certain objectives. These studies included:

- Algonquin Region Growth Study Plots (ARGS);
- Algonquin Polar Plots (APP);
- Algonquin Site Program Pine Study (ASP);
- Forest Health Plots;
- Forest Land Productivity Survey (FLaPS);
- Numerous Stem Analysis Projects;
- Local District/Area office plots; and,
- Beckwith Research Plots.

While these projects have provided useful information at specific management levels, the ability to extrapolate their results on a broader regional or Provincial scale has proven difficult, if not impossible. What they do provide, in some cases, is a network of plots or datasets that are suitable for inclusion within the regional and, ultimately, the Provincial G&Y program (section 5.4.2) as well as invaluable validation data sets for model development. In many cases, outputs of these studies have proven useful for stratification and productivity estimation purposes.

3.2 Process of Program Development

The lack of a corporate policy on the direction of Provincial G&Y work became evident in the late 1980's, with the numerous recommendations for improved forest information (Baskerville, 1986; OMNR, 1987; Hynard et al., 1987; Salterelli et al., 1989; Pinto, 1989). This recognition resulted in the OMNR Forest Management Committee being charged with developing a Provincial G&Y strategy. A strategy based on OMNR input was developed but following review was not accepted across the province as meeting the specific needs of the differing forest regions. It also became apparent that G&Y issues were not solely an OMNR issue. Various stakeholder groups, partners and co-operators expressed an interest in shaping a long- term strategy.

To enable all pertinent views and opinions to be expressed in the development of a Provincial G&Y program, a set of facilitated workshops were held during 1991. These consensus-building workshops were facilitated by an independent consultant, Environmental and Social Systems Analysts Ltd. (ESSA), who had developed experience in similar needs analysis/program development processes. Details of the processes used and the results of these workshops are found in the final reports from each workshop (McNamee et al., 1991 ESSA Ltd., and, Kurtz et al., 1991). The final document (Kurtz et al., 1991) outlines a

Provincial G&Y program including stratification considerations, sampling methodologies, species priorities and minimum data collection standards.

The ESSA workshop process provided the opportunity to develop consensus among individuals with many opinions and expectations. The result, although theoretical in some aspects, was a fairly well developed plan of action. The Provincial and Regional Master Plans are based upon the results of this process.

The Central Region Master Plan builds on the ESSA foundation and the Provincial Master Plan direction. While sampling requirements and species priorities may be tailored to regional needs, all minimum Provincial measurement standards will be met.

3.3 Program Purpose

The purpose of Ontario's G&Y program is to provide resource managers at all levels with enhanced predictive capabilities and understanding of forest stand dynamics and productivity under varied management options (OMNR, 1992).

The goals of the Ontario G&Y program are:

- to provide comprehensive G&Y information on Ontario's forest stands;
- to provide consistent, reliable and scientifically sound forest G&Y data;
- to provide a network of permanent sample plots (PSP's) for forest cover types that provide for long term forest monitoring;
- to develop and transfer tools and models for timber and other forest values (habitat, etc.) management.

A province as diverse in species, management systems and topography as Ontario, requires that regional priorities and perspectives be accounted for in the establishment of program objectives. The goals of the Central Region G&Y program are:

- to achieve the goals of the Ontario G&Y program within the priorities and context of the needs for Central Region;
- to develop a stratification system for sampling forest cover type priorities;
- to establish a network of G&Y PSP's across the region for priority cover types; and,
- to identify short and long-term information and modelling needs and develop a system for timely delivery.

3.4 Program Objectives

The objectives of the Provincial and Central Region programs naturally overlap to a high degree. They have been divided into short, medium and longterm objectives. Objectives that require Provincial coordination, and are therefore the joint responsibility of the Provincial and Regional programs, are italicised.

3.4.1 Short Term Objectives (1-3 years)

- *refine and test the stratification system used in the program;*
- *refine and test minimum standards for establishment of PSP's and refine sampling strategies and sampling design;*
- complete regional G&Y Master Plan;
- commence establishment of PSP network;
- review and evaluate existing G&Y datasets relative to minimum data collection standards and stratification systems to determine which plots and/or network of plots can be incorporated or maintained;
- assess existing G&Y models for applicability to Ontario; calibrate/validate chosen model(s) using existing data; implement appropriate model(s) and, determine additional data needs and model requirements;
- establish a chronosequence PSP series to provide interim data on stand development and dynamics to field resource managers;
- develop, test and validate local volume tables and individual volume equations for commercial tree species (including product volume tables where applicable);
- initiate the development and validation of site index curves;
- initiate the development and validation of stand density management diagrams;
- *design a Provincial database for collected G&Y data and enter existing PSP data into computer database format;*
- *design and produce software for DOS-compatible direct data entry devices for field collection of G&Y data;*
- provide summary factsheets of established PSP's;
- assist in the development of tools for habitat supply modelling; and,

- implement G&Y communication sessions to create and maintain staff and public awareness and interest in the G&Y program, and to provide training and obtain feedback on the use of G&Y models and deliverables.

3.4.2 Medium Term Objectives (3-5 years)

- *continue refinement and testing of the stratification system for the G&Y program;*
- develop preliminary G&Y models from available data for input into forest level wood and habitat supply analyses. These will include initial pure species models in northern Ontario for prioritized species, initial models of stand dynamics from chronosequence methods and mixed species models for the Great Lakes-St. Lawrence and Carolinian Forest; and,
- complete the establishment of the PSP network including initial plot measurements and retrospective measures from increment cores and stem analyses.

3.4.3 Long Term Objectives (5-30 years)

The long term objective of the G&Y program is the development and maintenance of forest stand dynamics and yield projection models. Some long-term deliverables of the program are:

- develop operational growth models validated with local PSP data to be used in forest level management decisions (including habitat supply components);
- develop predictive models for the evaluation of treatment responses which account for site characteristics and a variety of silvicultural treatment regimes;
- provide G&Y prediction tools for stands undergoing natural disturbance, from biotic and abiotic factors (e.g. fire, insects) through increased understanding of the processes involved in stand dynamics;
- provide field practitioners with practical tools and methods for relating site (Central Ontario Forest Ecosystem Classification) and productivity;
- provide stand development and succession information to forest managers in support of integrated resource management decision making
- *continue refinement and testing of the stratification system for the G&Y program;*
- maintain and upgrade G&Y models; and,
- remeasure and maintain PSP network including replacement and treatments.

4.0 Growth and Yield Program Structure

A Provincial/Regional G&Y technical committee provides a coordination function for the Provincial program. Regional G&Y program leaders, Provincial measurements and modelling staff and statistical support comprise the body of this committee. Funding and plot target assignments are proposed and approved by this committee. Modelling efforts to meet Regional priorities are handled through a proposal process. Each proposal is reviewed, rated, approved and funded appropriately. This process ensures minimal duplication of modelling efforts and efficient use of available funding resources.

G&Y related projects which may be of regional or local importance but which are ancillary to the Central Region portion of the Provincial G&Y program are submitted through the Central Region Science and Technology Client Steering Committee (CSC) process for ranking, recommendation and approval. The CSC is comprised of Regional client groups including Regional Science and Technology, Operations and Planning Sections, District/Area teams and regionally based forest industry.

The coordination and delivery responsibilities of the Central Region G&Y program currently reside in the Science and Technology section of the region. Two permanent positions: a G&Y program leader; and a G&Y program technician, are the individuals charged with the administrative and technical responsibilities of ensuring that a scientifically rigorous program is developed and maintained.

4.1 Growth and Yield Program Links

As was evident throughout the ESSA workshop process, G&Y concerns are not strictly isolated to the program itself. Regional science and technology and planning programs will have an integral contribution to the planning and input requirements of the regional G&Y program, dissemination of program outputs and their incorporation into operational resource management exercises.

Ongoing financial limitations emphasize the importance or rationalizing plot locations, numbers of plots and specification of common data collection standards. The Vegetation Management Alternatives Program (VMAP), Central Ontario Forest Ecosystem Classification Program (COFEC), Habitat, Hardwood, Conifer, Demonstration Forests Program and G&Y Programs have worked toward integrating quantitative data collection in all activities undertaken. Some specific areas of integration are outlined below.

Vegetation Management Alternatives Program

Current joint efforts include a pre-harvest prescribed burn in a white pine dominated stand in North Bay, and a replicated trial of shelterwood harvest spacing and follow up treatments in white pine in the Parry Sound District.

In both these trials, data is being collected in a manner that will allow both the G&Y and the VMAP program to utilize the information. PSP's established in these stands will allow the

long-term monitoring of changes for both programs' specific needs.

Central Ontario Forest Ecosystem Classification Program

The COFEC program has provided much of the foundation work necessary to initiate a G&Y program based on temporary and permanent sample plots. Initial stratification efforts of the G&Y program involved the use of the COFEC sampling matrix to understand the common species/site associations present in the region.

Collaboration continues between the two programs in utilizing similar stands for sampling, and when possible, similar plots for completion of both programs' sampling matrices. In addition, the G&Y program describes site conditions and attempts to collect vegetation species lists that will enable the G&Y plots to be keyed to an appropriate COFEC site type. This will allow productivity relationships to be investigated and developed within specific groups or individual site types. Future G&Y sampling will use COFEC site types as a key level of stratification.

Forest Habitat Program

Much effort has been focussed on developing an "ecosystem based" G&Y program rather than a strictly timber oriented initiative as witnessed historically. Data collection needs developed through the workshop process included variables that were deemed as important for the future modelling of habitat supply.

The Central Region Forest Habitat and Systems programs are developing stand and forest level habitat supply models for field practitioners based on the most current literature and tools. The Central Region G&Y program has incorporated additional necessary data collection variables into its regional program. These additions will allow habitat supply interpretations to be made of each plot as well as providing a stable foundation (PSP) for more long term monitoring of changes with and without stand level silvicultural intervention. The additional variables added to the sampling program include: an assessment of down-woody debris on the plot; and the presence and number of feeding, escape and nesting cavities.

Hardwood Program

The Central Region hardwood program has been involved with the Hardwood Silviculture group of the Ontario Forest Research Institute (OFRI) for many years. Collaborative efforts have included the remeasurement of hardwood PSP's, development and transfer of tree marking expertise, and studies aimed at educating OMNR staff and Industry in the importance and impact of reducing logging damage to sites and residual growing stock.

Many of the historical Hardwood program / OFRI Hardwood Silviculture collaborative efforts now have a G&Y involvement. Selected PSP's established by the Research Branch in 1977 are now incorporated into the sampling matrix of the G&Y program (see section

5.4.2). Other plots established to monitor logging damage will also continue to provide key information to the program. Future studies examining silvicultural treatments in tolerant hardwood stands along the North Shore/Algoma area will be established as a joint effort.

Modelling efforts undertaken in the past by this collaboration will now have financial and scientific support from the Regional and Provincial G&Y initiative.

Conifer Program

Early work in red and white pine by Merchant et al. (1989) in the development of the Pine Forest Ecosystem Classification spearheaded the development of the COFEC program by the Central Region Conifer program. Some of the plots originally established by the Pine FEC have been incorporated or evaluated for their suitability in the G&Y program.

Modelling initiatives (eg. site index development) by the Conifer and G&Y programs have been combined where possible to ensure compatibility between ventures and minimum duplication.

Demonstration Forests

The Demonstration Forests and the G&Y program have had opportunity to combine demonstration stands with the establishment of PSP's in Sault Ste. Marie and Pembroke districts. These plots, intended for professional staff development, will be specially signed to provide information about the forest's current state (timber and habitat) as well as changes occurring through the years through application of management practices.

4.2 Cross Regional Linkages

The G&Y program has been developed as a Provincial initiative. It was recognized at the start that one region alone could not adequately sample all species and management options. To achieve a sufficient sample size of these combinations, regions have prioritized appropriate species and management options. The remaining species and combinations, in most cases, have been prioritized by an adjoining region. These sampling efficiencies are a direct benefit of a Provincially coordinated program.

Specific examples of such complementarity in Central Region's sampling strategy are found in species such as jack pine and black spruce. These species are a major focus of the Northeast and Northwest Regional programs. Central Region's approach will be to install a minimal number of plots within our identified site conditions and compare recorded growth and dynamics with those of the Northeast and Northwest Regions. Where and when differences are noted, additional plots will be added to account for our variation (due to climate, etc.). A similar approach for white pine is being used in the Northeast Region where a few long-term plots are being established for a relatively small proportion of the landbase. Information gathered by the Central Region, if deemed appropriate for developing and driving stand simulators, yield curves, etc., will be shared with Northeast and Northwest

Regions.

The opportunities to work on common modelling priorities are being handled through the modelling and productivity program (refer to section 6.0) component of the G&Y initiative. A coordinated approach to modelling commonalities among the four regional programs will ensure efficient use of time and manpower in all efforts.

4.3 Industry and Academic Partners

The role of private industry in the Central Region G&Y program will be evolved over the remainder of the decade. Industry's involvement in the ESSA process was recognized as only the first step in having industry actively participate as a partner in long term delivery of a portion of the program.

In the near future, Provincial or Regional G&Y cooperatives will be investigated as a potential vehicle for the operational delivery and product priority setting of a G&Y program. This cooperative arrangement is envisioned to have equal participation from forest industry, university and colleges, and government agencies.

5.0 Growth and Yield Program Components

5.1 Stratification

The purpose of stratification is to ensure sampling efficiency and to reduce all known variation within the population being studied. Figure 3 outlines the proposed Provincial G&Y program stratification with the model being implemented within Central Region. Although the two are similar, some deviations have been made to tailor the stratification for sampling efficiencies in the Central Region forest conditions.

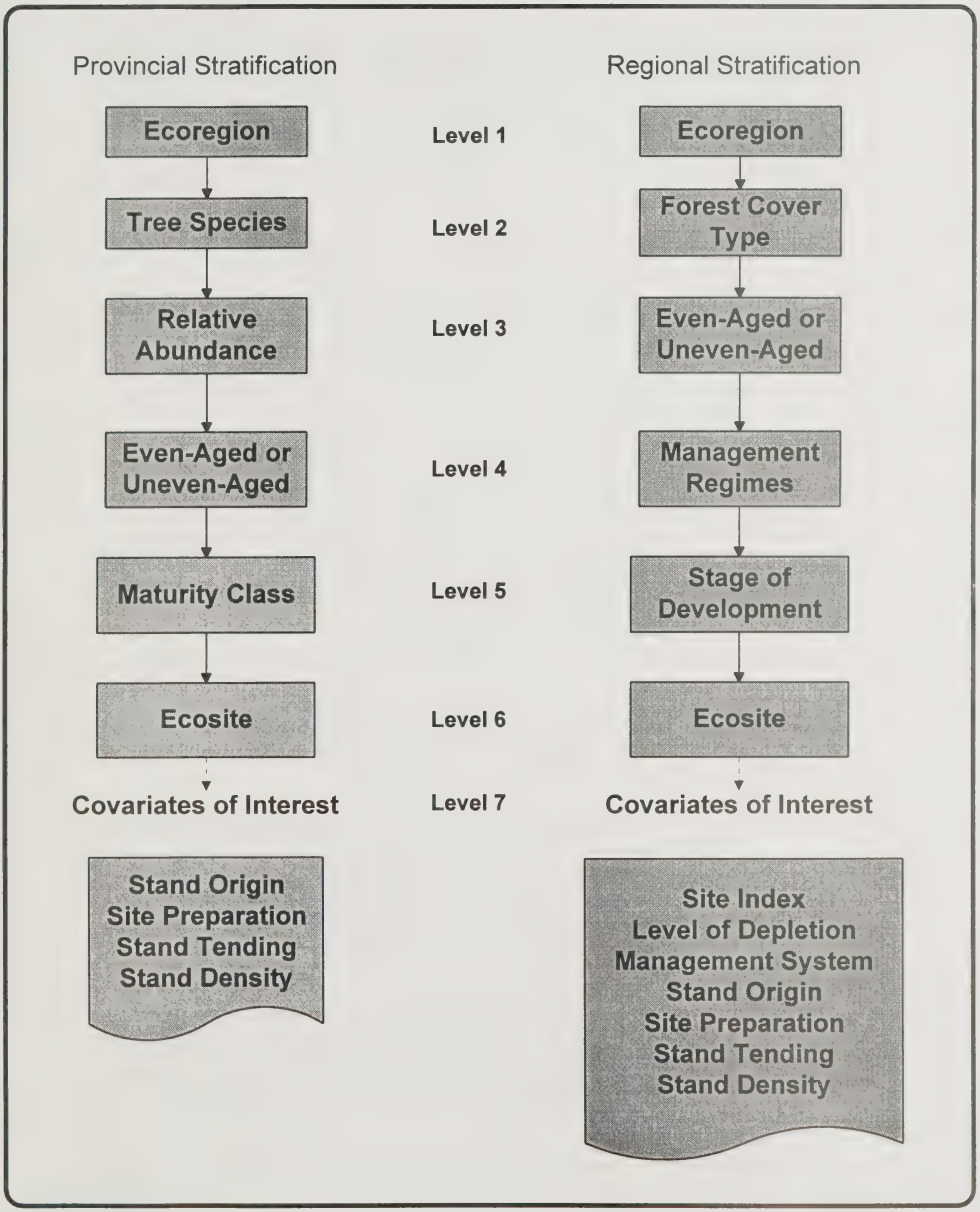
5.1.1 Ecoregion

Ecoregions (section 2.3) are broadly mapped units of similar macroclimatic factors (mean annual temperature, length of growing season, etc.). Their inclusion into the G&Y stratification is to minimize variation by providing a basis for sampling other strata within a similar climatic and physiographical areas.

5.1.2 Forest Cover Type

The sampling of forest tree species as established by the Provincial stratification strategy falls short in adequately representing the species variation found in many of the forest cover types within Central Region. Individual species rarely exist in a forest unit abundantly enough or uniformly enough to allow representative sampling. Section 5.2 outlines the forest cover type strategy being utilized by Central Region.

Figure 3. Provincial and Regional Stratifications



The concept of relative abundance is intended to reduce sampling variation within a given species type by restricting replication of plots to pure, dominant and mixedwood groupings. As defined in the suggested Provincial stratification, relative abundance is a classification with >70% by target species basal area, dominant as 30% - 70% and mixedwood as < 30 %. Preliminary sampling indicated that definite groupings of pure, dominant or mixedwood conditions could not be found for the majority of species prioritized for sampling. For this reason, the concept of relative abundance has been removed from the formal Central Region stratification chart and accommodated in a forest cover type sampling approach (section 5.2).

5.1.3 Even or Uneven-Age Characteristics

The forest types of Central Region consist of even-age and uneven-age forest conditions. These characteristics determine management options for the forest types. These different management options will affect stand and forest dynamics.

5.1.4 Management Regimes

The management regimes level of the stratification is intended to provide information on unmanaged (undisturbed) stands and stands that are managed (disturbed) using sound silvicultural practices (partial harvesting systems). For stratification purposes, individual management approaches (i.e. shelterwood, selection, etc.) are not identified. Post-stratification of system and level of depletion will be used to provide response information by silvicultural system. However, partial harvesting system priorities have been established for tactical purposes (section 5.4.1).

Plot allocation within the disturbed class of this stratum will follow two approaches:

i) Plots will be established in stands scheduled for harvesting in the current management cycle. These plots will initially collect baseline cover type data and allow for long term monitoring of the dynamic response of the stems following treatments.

ii) Plots will be established in stands that have been harvested five years previously and exhibit suitable characteristics (i.e. stumps, harvesting records, etc.) to allow for back- projection of original conditions. Plots established in this manner will allow for an early estimation of growth rates for modelling and calibration purposes.

5.1.5 Stage of Development

Central Region has adopted a stand stage-of-development approach versus a maturity class (age-class) approach in level 5 of the Provincial stratification. It is recognized that different tree species reach different stages of stand development on different sites at different ages. A stage of development approach to chronosequence sampling ensures that critical time periods are sampled in a stand's development history.

5.1.6 Ecosite

Ecosite is the sixth level of the regional stratification. Dominant soil texture groups for priority forest cover types were identified in conjunction with the COFEC program and its sampling matrices (Table 4). Appropriate numbers of plots were calculated to provide for adequate sampling of these dominant types.

The heterogeneity of site conditions may require ecosite analysis using a post-stratification approach.

5.1.7 Covariates of Interest

Density

To ensure realistic estimates, the sampling program must quantify growth and dynamics across a range of densities for common site types (or ranges of site index or stand structures). Ongoing post-stratification of plots into density classes, site index ranges, etc., will be undertaken to ensure adequate sampling levels (numbers of plots and geographic range) are being achieved.

Future sampling efforts will focus on establishing plots in under-sampled density classes.

Site Index

Site index will be the productivity estimator for even-aged stand conditions. Current data collection standards allow for site index calculation. As with density, it is critical to sample across the range of site index classes available, to provide adequate estimates. Ongoing post-stratification of the plots will be undertaken to ensure the installation of plots across a range of conditions.

Future sampling efforts may be directed at completing sampling cells of site index classes, which would necessitate more height and age sampling prior to plot location and establishment.

Level of Depletion and Management System

The sampling of levels of depletion within specific management systems utilized in tolerant hardwood and white pine stands is a priority. The major requirement for growth and yield data in Central Region is from managed stands. Sampling will be weighted to specific management regimes (section 5.4.1) and their response to treatment based on sampled depletion levels.

Site Preparation - Stand Origin - Stand Tending

Site preparation equipment and stand tending methods are covariates of interest to the program which can both be utilized as post-stratification criteria.

COVER TYPE	Very Shallow <30 cm all textures		Sandy vcS,LvcS, Cs, LcS, mS, LmS, fS, Lfs			Coarse Loamy vfS,LvfS,SivfS,SivcS,SicS SimS,SifS,vcSL,cSL,mSL,fSL, vfSL		Fine Loamy / Clayey SCL,CL,SiCL,SC,SiC,C	Silty Si, SiL		Organic >40 cm Organic
	Dry	Fresh	Dry	Fresh	Moist	Fresh	Moist	Fresh / Moist	Fresh	Moist	
Sugar Maple - Beech - Yellow Birch											
White Pine											
Red Pine											
Northern Red Oak											
Aspen											
White Birch											
Hemlock											
White Spruce											
Black Spruce											
Jack Pine											

Table 4. Central Region Cover Type Dominant Site Occurences

Stand origin has been removed from the stratification for tactical (total number of plots required) reasons. Its exclusion is based on the hypothesis that 10 year old plantations or naturally occurring stands (fire origin, etc.) are starting to exhibit growth trends attributed to density and site relationships, independent of their origin (planted, seeded or natural). It is assumed that effects of site preparation are negligible at this stage of stand development.

5.2 Priority Forest Cover Types of Central Region & Species Associations

The original intent of the Provincial G&Y program was to sample within an individual tree species context identified by a method of prioritization (economic, aesthetic value, etc.). Unfortunately, in the Great Lakes-St. Lawrence forests, the tree species diversity is much more variable than, for example, large sandy areas of jack pine stands or organic black spruce sites. This heterogeneity of tree species within commonly recognized stand types required that another method of stratification be sought for sampling purposes.

Sampling on the basis of recognized forest cover types was chosen as the most appropriate method for Central Region. This approach is also being applied in the developing Forest Ecosystem Classification system of Central Region (therefore allowing some information and data to be shared between the programs), and the Southern region G&Y program. The definition and description of forest cover types used were taken from Forest Cover Types of the United States and Canada (SAF, 1980).

The definition used for forest cover type within the Central Region G&Y program is: *Forest cover type, crop type, stand type - more particularly a category of forest defined by its vegetation (particularly its composition) and/or locality (environmental) factors* (Ford-Robertson 1971*)*. Simplified, a forest cover type is a descriptive classification of forest land based on the present occupancy of an area by a single tree species or groups of species.

A forest cover type is identified by 3 criteria:

1. The dominant cover must be of trees (25% of the area should be covered by tree crowns);

2. The type must occupy a fairly large area of the aggregate, but not necessarily in continuous stands; and,

3. Recognition of a forest cover type must be based on biological considerations.

Ten forest cover types have been identified for sampling. They are the: sugar maple-beech-yellow birch; eastern white pine; red pine; northern red oak; aspen; white birch; hemlock; white spruce; black spruce; and jack pine cover types. It is recognized that these forest types are not pure and that transitional types occur between them. Some of this known variation within the cover types will be sampled as part of the natural mixed condition of the forest type.

Other cover types such as the spruce-fir and the birch-fir are not being omitted from G&Y investigation. In addition to others (including refined versions of the priority cover types),

they will be sampled on completion of initial efforts with the identified priority cover types.

A definition and composition description (SAF, 1980) of each of the 10 priority forest cover types follow:

Sugar Maple-Beech-Yellow Birch

Sugar maple, American beech, and yellow birch are the major species and together account for most of the stocking within this forest cover type. The species associated with this cover type include: red maple, hemlock, white ash, black cherry, basswood, northern red oak, white pine, balsam fir, American elm, rock elm, red spruce, white spruce and ironwood. American beech diminishes within this cover type as one moves north and west within the Great Lakes St. Lawrence Forest Region while yellow birch becomes less prevalent as one moves south.

Eastern White Pine

Eastern White Pine constitutes a majority of the stocking and characteristically occurs in pure stands. Its species associations differ as one moves between light and more heavily textured soils and as one moves toward the northern limits of its range. The species include red pine, trembling and large tooth aspen, red maple, pin cherry, white oak, white birch, black cherry, white ash, northern red oak, sugar maple, basswood, hemlock, red spruce, balsam fir (subordinate associate in the northerly locations), white spruce, black spruce and northern white cedar.

Red Pine

Red pine occurs in pure stands or makes up a majority of the stocking mixture with eastern white pine, jack pine, or both. On fine sands, associates include red maple, northern red oak, white spruce and balsam fir. On coarser, drier soils, associations include jack pine, white pine, trembling and large tooth aspen and white birch.

Northern Red Oak

Northern red oak dominates the stocking in this forest cover type (and in some areas may form pure stands). The species associations of this cover type vary according to geographic locality. In Central Region, associate species include sugar maple, black cherry, white ash, white oak, white pine and American Beech.

Aspen

Trembling aspen and largetooth aspen together constitute a majority of the stocking in this widespread forest cover type. Trembling aspen tends to be the predominant species and may occur in extensive pure stands. Largetooth aspen's contribution to the stocking percentage diminishes as one moves north and west. Associates include white birch, pin cherry, white spruce, balsam fir, red maple, balsam poplar (moister sites) and jack pine.

White Birch

White birch often occurs in pure stands or in stands where it forms the majority of the stocking. The most common overstory associates are trembling, largetooth aspen and pin cherry. Other associate species, yellow birch, red maple, northern red oak, white pine, jack pine, balsam fir and white spruce are common throughout its wide range.

Eastern Hemlock

The majority of the eastern hemlock forest cover type consists of relatively pure stands. Among the common associated species are white pine, balsam fir, red spruce, sugar maple, beech and yellow birch. Some association with northern red oak, white oak, basswood, black cherry, red maple and white ash occurs on the eastern portion of its range.

White Spruce

The white spruce cover type occurs rarely in pure stands. Most often it occurs in mixed stands in which white spruce is the major component. Black spruce, white birch, trembling aspen, red spruce and balsam fir are common associates. Yellow birch and sugar maple are occasional associates.

Black Spruce

The black spruce cover type occurs in mainly pure stands or, when mixed with other species, constitute the majority of the stocking. This forest cover type occupies many different site types within its range and therefore has many common tree species associations. In the boreal forest range (moist to wet), the most common associations are with white spruce, trembling aspen, balsam fir, white birch, white cedar and tamarack. On the drier and shallower sandy, boreal transitional sites, associations with jack pine (white pine, white cedar) are most common. As one moves to the more southerly end of the cover types range, associations are with northern white cedar, tamarack, black ash and red maple.

Jack Pine

The jack pine cover type present within the transitional Great Lakes-St. Lawrence Forest / Boreal forest regions consists of jack pine growing with white birch, trembling aspen and sometimes Eastern white pine and red pine species. In many situations, black spruce and balsam fir form the understorey on the common well-drained sandy and gravelly soils.

5.3 Sampling Strategy

The primary goal of the G&Y program is to better predict tree biomass growth and stand dynamics over time with and without silvicultural intervention (OMNR 1992). To gather data to permit this requires repeated measurements of tree and stand development. PSP's have been selected to provide the platform for the necessary repeated measurements because of their ability (once compiled) to provide precise estimates of growth, mortality and treatment effects.

A nested, or multi-stage sampling design has been selected as an appropriate system for PSP establishment. The sample elements described on the plot include trees, lesser vegetation, site and soils. For efficiency of estimation, these individual elements should be sampled in direct proportion to their variability (OMNR 1992). This requires that sample elements that occur frequently or show low variability are sampled on small areas. The rarer or more variable elements require larger sample areas.

The multi-stage PSP used in the Ontario G&Y program has 3 stages (Figure 4). The first-stage sample unit, which requires the largest sample area, is used to monitor tree mortality. Nested within this sample unit are the smaller, randomly located second-stage sample units (growth plots) for recording individual tree characteristics used to monitor growth. Within each second-stage sample unit, smaller third stage sample units (shrub and regeneration/vegetation plots) are randomly selected to assess shrubs, tree regeneration and lesser vegetation (OMNR 1992). A description of collected data element attributes is listed in section 5.3.1.

Newly established PSP's will be supplemented with existing PSP's/TSP's (some upgraded to Provincial standards) where possible. Existing plot networks provide valuable data, which in many cases, will be unavailable until many remeasurements of the newly established plots are completed.

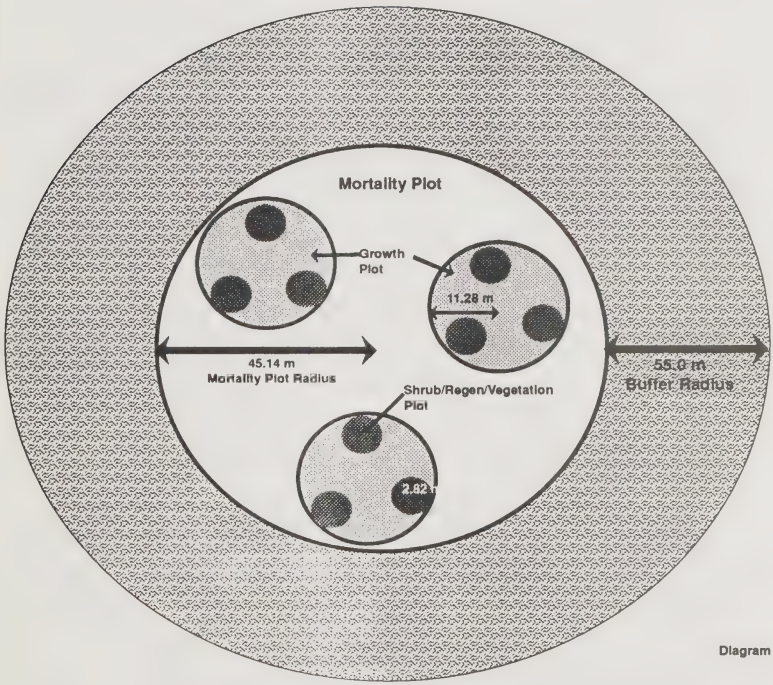
5.3.1 Data Collection Strategy

Section 5.3 describes the permanent sample plot design being used by the Ontario G&Y program (refer to Figure 4). The purpose of the data collection strategy is to ensure that all crucial data elements are collected consistently and at expected levels of quality in order to assist in resource management today and in the future. The minimum data collection needs were outlined in the ESSA workshop process. Provincial minimum data collection standards were developed from this list (Appendix A). Additional regional variables have been incorporated to ensure that applicable information is being collected for the multi-management concerns of Central Region. Some examples of these additions are the assessment of down-woody debris and nesting/feeding sites located on the sample plots, which provide some habitat information. The variables measured at each stage of the plot assessment and measurement are listed below.

General Plot Information Variables

- Plot number
- UTM number
- Ecoregion
- Plot elevation
- Ownership
- Township/Lot/Concession
- FRI stand information (Stand #)
- Aerial Photo # and photocopy
- Plot area, shape and dimensions
- Stand origin
- Plot status (active, abandoned)
- Past treatment information
- Date of plot establishment
- Detailed plot location map
- Crew members

Figure 4. Ontario's G&Y Permanent Sample Plot Design



Site and Soil Description

- Slope position
- Slope percent (i.e. 10%)
- Aspect
- Landform type (esker, kame, etc.)
- Mode of parent material deposition (fluvial, etc.)

Information based on 3 auger samples per second-stage plot and divot samples.

- Soil texture and depth of each horizon
- Depth to gley
- Depth to mottles
- Depth to carbonates
- Depth to bedrock
- Depth to seepage

Mortality Plot - 1 (First-stage plot - 45.14 m radius - 6400m^2)

- Tree species
- Mortality condition for dead standing trees
- Dead and downed woody debris assessment (3 - 45.14m transects)

Growth Plots - 3 (Second-stage plot - 11.28 m radius - 400 m^2)

For all trees 2.5 cm dbh and larger

- Tree species
- Tree diameter at breast height
- Height at which dbh is measured
- Assigned a permanent tree number
- Assessed for live or dead status
- Assigned mortality code if required
- Each tree is stem mapped (azimuth and distance from plot centre)
- Tree origin (natural/planted)
- Crown class (dominant, etc.)
- Tolerant hardwood quality class (6 classes)
- Tree deformities (broken tops, logging damage, etc)
- Sample of total heights and heights to base of live crown
- Cavities (number, size of cavity and type)
- Estimate of crown closure (trees 10 m and taller)

Regeneration/Vegetation/Shrub Plots - 9 (Third-stage plot - 2.82 m radius - 25 m^2)

- Percent cover assessment for herbs, sphagnums, ferns, feather mosses, bryophytes, grasses, sedges, cladina spp., lichen
- percent cover assessment by shrub species for the 0.00 m to 0.49 m height class
- percent cover assessment by tree species for trees < 50 cm in height
- Number of trees by species from 50 cm to 1.30 cm
- Number of trees by species > 130 cm and < 2.5 cm dbh
- Shrub species
- Percent cover assessment by height classes (0.50 m to 1.99 m or 2.00 m to 10.0 m)

Buffer Measurements (destructive sampling on selected trees)

- Tree species
- Dbh
- Total tree height
- Total tree age
- Breast height age
- Bark thickness
- Growth increment (cm) for past 5, 10 and 15 years
- Complete soil pit if necessary
- Stem analysis trees

Additional Measurements

- Crown radius
- Fire fuels

5.3.2 Data Consistency

Historical G&Y efforts throughout Ontario attempted to collect data critical to the project's objectives. This led to many different methodologies and levels of data collection standards. The current Provincial initiative has attempted to eliminate this problem by imposing a set of Provincial minimum standards for data collection programs involved in G&Y studies. These Provincial minimum standards, published in A Master Plan to Examine Forest Growth and Dynamics in Ontario (OMNR 1992), are included as an appendix to this document .

These standards are accepted and followed by Central Region in all G&Y plot activities. Additional fields of data collection have been added to the Provincial minimum standards to enhance the predictive capability of the base data. These additions are incorporated in the Central Regions Field Manual for Permanent Sample Plot Establishment.

5.3.3 Data Integrity

The responsibility for data collection integrity is shared by the region and province by ensuring an adequate quality assurance process. Regional staff are responsible for ensuring that a high level of staff competence is maintained throughout the program areas. This will involve regular audits of completed plots together with Provincial staff. These quality assurance audits will maintain and ensure an appropriate degree of consistency and integrity in the types and accuracy of data being collected.

5.3.4 Data Management

The G&Y corporate database is under the direction of a Provincial database manager who will ensure maintenance of data consistency and integrity. The manager's responsibility will be to develop appropriate database structures and to ensure that consistency in data fields and coding conventions are followed. The database manager's other responsibilities include the development of summary outputs for the development of regional plot fact sheets.

Regional database management is the responsibility of the Central Region G&Y program leader. The database, developed in harmony with the Provincial database structure, will include additional fields of interest to the region (i.e. nesting/feeding sites, down-woody debris information) that are not currently included in the Provincial structure.

5.3.5 Entry and Validation

The current system employed for plot data collection involves the use of paper tally forms. A data entry program on a DAP PC9000 has been developed and is to be tested in coming field seasons. The use of electronic data collection devices will eliminate some of the cost of data entry of paper tally forms and ensure the use of common coding conventions at the plot site.

Future remeasurement of PSP's with electronic data collection devices will reduce field remeasurement error by providing an 'on-line' validation routine against previous measurements.

5.3.6 Plot Integrity

The long-term protection of these plots is a priority of the program. Plot integrity is maintained by:

- G&Y program/district communication;
- record keeping; and,
- Area of Concern Planning process.

G&Y plots that are established in Central Region are directed, in as many cases as possible, to stands identified by district staff. It is the intent of the G&Y program to minimize "stumbling onto plots", while regular district/area activities are being carried out, by having locations of plots well documented and available.

Each PSP that is established will have a clear location (map and aerial photo coverage, UTM coordinate) and long-term intent of the plot documented in a G&Y plot binder that will be prepared for each district/area office. Area of concern (AOC) planning will be used to identify and protect the plots located in areas involved in timber harvesting activities. Plot locations will be placed on values maps.

Many of the plots (75%) will have a prescription of "normal management" assigned to them. For these plots, harvesting and other silvicultural treatments are to be applied in a similar fashion to that of the stand. A major focus of the Central Region G&Y program is monitoring impacts and modelling stand dynamics following normal management operations.

5.4 Plot Allocation Strategy

The plot allocation strategy for Central Region is based on the sampling of the forest cover

types listed in 5.2 prioritized by past, present and estimated potential future economic and cultural value. Southern Region uses a similar sampling approach that allows for priority species sampling (Pw, Or, Mh/Be/By) to be combined within the shared ecoregions.

Cover types such as eastern white pine and red pine have had historical economic importance in the region. The future economic and social requirements for stands of these species are well understood.

The need for more information on the Or, Mh/Be/By cover types is critical to ensure the implementation of sound scientific silviculture. Current management prescriptions involving partial harvesting systems in the tolerant hardwood cover type along the North Shore area of the province are based on guidelines developed for similar species matrices growing in the Algonquin Park area of the province. It is a priority of the program to establish PSP's along the North Shore to develop management guidelines appropriate to the area. Work will involve operational trials with the Regional hardwood program and research guidance from OFRI.

The poplar and white birch cover types have always had a low value as pulpwood species within the region. They are currently gaining more attention because of their abundance and suitability for the production of oriented strand board. The Central Region G&Y program will concentrate on establishing plots in these cover types to provide crucial information on their dynamics.

The hemlock cover type provides a substantial contribution to wildlife habitat. Little is known about its dynamics. Regeneration of the species in areas with high browse pressure appears to be minimal. The establishment and maintenance of a plot network (using existing plots located in conjunction with Queen's University and the VMAP program) will provide needed information.

Sampling of the Sb, Sw and Pj cover types are a priority of the northern regions. Central Region's program will expend very little effort on these cover types in shared ecoregions. Replicated PSP's will be established in the Nipissing ecoregion to allow comparison of growth (and future model calibration) rates between the ecoregions.

The primary sampling element used in the development of the sampling strategy and plot distribution system is the ecoregion. Three ecoregions require sampling: The Nipissing, a portion of Chapleau Plains, and a small segment of the St. Laurent. Priority cover types were assigned (or weighted) to each ecoregion. The weighting was based on replication of cover types in an ecoregion where the cover type was identified as a priority. Cover types that are shared and were identified as a priority in neighbouring ecoregions, were allocated fewer plots for the sake of sampling efficiency. The cover type priority by ecoregion is outlined in Table 5.

It is estimated that a minimum of 735 PSP's are required to sample the list of forest cover types identified as priorities for the region. The number of plots is calculated based on the stratification presented in section 5.1. Initial plot allocation is based on area estimates by district/area and age-class (grouped for sampling on expected species 'stage of development') recorded in current Forest Resources Information (FRI) ledgers. This information is

recognized as imperfect but provides an adequate estimate of where, in Central Region, suitable cover types exist to be sampled. District age-class areas were calculated as a percent of the total ecoregion area and plots assigned accordingly to the districts. The attempt at sampling across ranges of age-classes or 'stage-of-development' classes is intended to provide a chronosequence approach to quickly, although crudely, representing potential trends of growth and stand dynamics. These approximated trends of stand development can be refined with future remeasurements.

Tables 6, 7 and 8 show initial district/area and regional allocations for plot establishment. The G&Y program recognizes that actual stand occurrences suitable for plot establishment will differ somewhat from the allocations. This discrepancy in conjunction with financial pressures means that in many cases only a subset of a district/area's allocation will be established in the initial sampling years.

	Ecoregions		
Cover Type	Nipissing	Chapleau Plains	St. Laurent
Mh/Be/By	High	High	Low
Pw	High	High	Medium
Pr	High	High	Low
Or	High	High	Medium
Pt	High	Medium	Low
Bw	High	Medium	Low
He	High	Medium	Low
Sw	High	Medium	Low
Sb	High	Medium	Low
Pj	High	Medium	Low

Table 5. Cover Type Sampling Priority by Ecoregion.

Sampling or establishment crews will be required for future years in order to complete/supplement the sampling matrix. Approximately 80% of the St. Laurent ecoregion falls within the Southern Region administrative boundary. Cover types in Central Region identified as low or medium priorities are being sampled as high priorities within the Southern Region program.

5.4.1 Management System Sampling Priorities

While the establishment and collection of base-line data in unmanaged stands is a broad-based Provincial priority, some of Central Region's forest cover types require more intensive G&Y data collection information on stands undergoing varied, partial harvesting systems. The Mh/Be/By, Or and Pw cover types are the immediate cover type associations selected for the collection of growth and recruitment information following management intervention.

Table 9 outlines, by cover type, management system priorities for initial sampling efforts.

Central Region Sampling Matrix

ECOREGION / COVERTYPE	Establishment		Crown Closure		Mature	Overmature	Unmanaged			Even Age Management			Uneven Age Management			
	Undisturbed	Disturbed	Undisturbed	Disturbed	Undisturbed	Undisturbed	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	
White Pine Cover Type																
Nipissing	9	9	9	9	9	9										54
Chapleau Plains	9	9	9	9	9	9										54
St. Laurent	1	2	1	2	1	1										8
Red Pine Cover Type																
Nipissing	9		9		9	9										36
Chapleau Plains	9		9		9	9										36
St. Laurent	1		1		1	1										4
Hemlock Cover Type																
Nipissing	0		9		9	9										27
Chapleau Plains	3		3		3	3										12
St. Laurent	0		0		1	1										2
Jack Pine Cover Type																
Nipissing	9		9		9	9										36
Chapleau Plains	3		3		3	3										12
St. Laurent	0		1		0	1										2
White Spruce Cover Type																
Nipissing	9		9		9	9										36
Chapleau Plains	3		3		3	3										12
St. Laurent	0		1		0	1										2
Black Spruce Cover Type																
Nipissing	9		9		9	9										36
Chapleau Plains	3		3		3	3										12
St. Laurent	0		0		0	0										0
Sugar Maple - Beech - Yellow Birch Cover Type																
Nipissing							9	9	9	9	9	9	9	9	9	81
Chapleau Plains							9	9	9	9	9	9	9	9	9	81
St. Laurent							1	1	1	1	1	1	1	1	1	9
Red Oak Cover Type																
Nipissing							9	9	9	9	9	9				54
Chapleau Plains							9	9	9	9	9	9				54
St. Laurent							1	1	1	1	1	1				6
Aspen Cover Type																
Nipissing							6	6	6							18
Chapleau Plains							3	3	3							9
St. Laurent							1	1	1							3
White Birch Cover Type																
Nipissing							9	9	9							27
Chapleau Plains							3	3	3							9
St. Laurent							1	1	1							3
	77	20	88	20	87	89	61	61	61	38	38	38	19	19	19	735

Table 6. Central Region Sampling Matrix

Regional Hardwood Plot Allocation By Stand Development Stage

Ecoregion	Districts/Areas	Sugar Maple - Beech - Yellow Birch									Red Oak						Aspen			White Birch			TOTAL
		Unmanaged			Even Age Management			Uneven Age Management			Unmanaged			Even Age Management			Unmanaged			Unmanaged			
		Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	Sapling	Poles	Sawlog	
Nipissing	Sudbury/GtLakes	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	2	2	4	3	1	16
Nipissing	Parry Sound	0	1	0	0	2	1	0	3	1	1	1	1	1	1	1	0	1	1	0	0	1	17
Nipissing	Bracebridge	0	1	1	2	2	2	1	3	2	2	2	2	2	2	2	1	0	0	0	0	0	27
Nipissing	Whitney	0	1	1	2	2	3	2	2	6	1	1	1	1	1	1	1	2	3	1	2	2	36
Nipissing	Bancroft	1	1	1	1	2	1	1	2	1	2	2	2	2	2	2	1	2	1	0	1	0	28
Nipissing	Minden	3	1	1	4	1	1	4	1	0	1	1	1	1	1	1	0	0	1	0	0	1	24
Nipissing	Pembroke/Nip	1	0	1	2	1	1	2	1	1	2	2	2	2	2	2	5	2	1	1	0	1	32
Chap. Plains	Sudbury/Boreal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chap. Plains	Temagami	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0	1	1	1	0	6
Chap. Plains	North Bay	1	3	3	1	1	0	2	2	3	3	3	3	3	3	3	1	1	0	0	1	0	37
Chap. Plains	Espanola	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	4
Chap. Plains	Blind River	2	1	1	2	3	2	3	2	2	3	3	3	3	3	3	1	1	1	1	1	1	42
Chap. Plains	Sault Ste. Marie	3	3	3	7	5	5	6	6	6	3	3	3	3	3	3	0	0	0	1	0	1	64
St. Laurent	Pembroke	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	21
		13	13	14	22	21	17	22	23	26	19	19	19	19	19	19	13	13	13	10	10	10	354

Saplings 2.5 - 9.9 Poles 10.0 - 25.9 Sawlogs 26.0 - 50.0+

Table 7. Regional Hardwood Plot Allocation by Stand Development Stage

Regional Conifer Plot Allocation By Stand Development Stage

Ecoregion	Districts/Areas	White Pine						Red Pine				Hemlock			
		Establishment		Crown Closure		Mature	Overmature	Estab.	Crown Clos.	Mature	Overmature	Estab.	Crown Clos.	Mature	Overmature
		Undisturbed	Disturbed	Undisturbed	Disturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed
Nipissing	Sudbury/GtLakes	3	5	1	1	2	2	3	2	3	8	0	0	0	1
Nipissing	Parry Sound	2	1	1	6	2	2	0	1	0	0	0	7	3	1
Nipissing	Bracebridge	1	0	0	0	0	0	0	1	0	0	0	0	1	1
Nipissing	Whitney	1	2	0	2	3	2	3	1	3	0	0	0	1	6
Nipissing	Bancroft	1	0	1	1	0	1	1	1	1	0	0	1	1	0
Nipissing	Minden	1	1	1	1	0	0	0	1	0	0	0	1	3	0
Nipissing	Pembroke/Nip	0	0	1	2	2	2	2	2	2	1	0	0	0	0
Chap. Plains	Sudbury/Boreal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chap. Plains	Temagami	3	4	3	3	2	3	2	0	2	6	0	0	0	0
Chap. Plains	North Bay	3	3	1	1	2	1	3	1	3	0	0	0	2	2
Chap. Plains	Espanola	1	0	0	0	1	1	1	1	3	1	0	3	1	1
Chap. Plains	Blind River	2	2	3	3	2	2	3	7	1	1	3	0	0	0
Chap. Plains	Sault Ste. Marie	0	0	2	2	2	2	0	0	0	1	0	0	0	0
St. Laurent	Pembroke	1	2	1	2	1	1	1	1	1	1	0	0	1	1
		19	20	15	24	19	19	19	19	19	19	3	12	13	13

Ecoregion	Districts/Areas	Jack Pine				White Spruce				Black Spruce				TOTAL
		Establish.	Crown Clos.	Mature	Overmature	Establish.	Crown Clos.	Mature	Overmature	Establishment	Crown Closur	Mature	Overmature	
		Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Undisturbed	Disturbed	
Nipissing	Sudbury/GtLakes	0	1	1	1	0	0	0	0	0	0	0	0	34
Nipissing	Parry Sound	0	6	5	0	1	1	2	1	1	1	2	1	47
Nipissing	Bracebridge	0	0	0	0	4	2	1	1	4	2	1	2	21
Nipissing	Whitney	6	2	2	1	3	6	3	2	4	6	5	4	68
Nipissing	Bancroft	3	0	0	0	0	0	1	1	0	0	1	1	16
Nipissing	Minden	0	0	0	0	0	0	0	1	0	0	0	1	11
Nipissing	Pembroke/Nip	0	0	1	7	1	0	2	3	0	0	0	0	28
Chap. Plains	Sudbury/Boreal	0	0	0	0	1	1	1	1	1	1	1	1	8
Chap. Plains	Temagami	1	1	1	1	0	0	0	0	0	0	0	0	32
Chap. Plains	North Bay	1	0	1	1	0	1	1	0	0	1	1	0	29
Chap. Plains	Espanola	1	0	0	0	0	0	0	0	0	0	0	0	15
Chap. Plains	Blind River	0	2	1	0	1	0	0	1	1	0	0	1	36
Chap. Plains	Sault Ste. Marie	0	0	0	1	1	1	1	1	1	1	1	1	18
St. Laurent	Pembroke	0	1	0	1	0	1	0	1	0	0	0	0	18
		12	13	12	13	12	13	12	13	12	12	12	12	381

Table 8. Regional Conifer Plot Allocation by Stand Development Stage

The ranking of management systems for sampling is based on current knowledge of silvicultural practice. Historic, alternative management approaches have been abandoned for more scientifically sound and sustainable practices.

Plot allocation was weighted more heavily to the management systems of today and the future. However, some investment will be made in stands that, in the past, were managed using alternate methods. It will be important to have sound estimates on growth and development of these stand types in view of future wood supply demands.

	Priority Management Systems For Sampling		
Cover Type	Priority #1	Priority # 2	Priority #3
Mh//Be/By	Selection	Shelterwood	No Management
Pw	Shelterwood	Seed Tree	No Management
Pr	No Management	-	-
Or	Selection	Shelterwood	No Management
Pt	No Management	-	-
Bw	No Management	-	-
He	No Management	-	-
Sw	No Management	-	-
Sb	No Management	-	-
Pj	No Management	-	-

Table 9. Management System Sampling Priorities

5.4.2 Incorporation of Existing Data

The Central Region G&Y program has the advantage of building on various sets of historical G&Y efforts. In order to provide earlier short-term products the use of these data sets in the regional program is a high priority. The past G&Y efforts include:

Algonquin Region Growth Study Plots (ARGS)

264 Mh dominated plots were established in 1977 by forest research. Each has had a minimum of 2 remeasurements. Central Region G&Y program has upgraded and incorporated 48 plots to Provincial growth plot minimum standards. The remaining plots will be maintained by G&Y and OFRI in their continuing Hardwood Silviculture research program. Data sets collected by both parties will be shared for development of resource management tools.

Algonquin Polar Plots

346 Mh/Be/By cover type and 15 Pw cover type plots were established in 1986 to evaluate timber marking activities. The plots were remeasured in 1991. Data from this study is shared with the Central Region G&Y program and OFRI Hardwood Silviculture program. These plots provide excellent independent data sets for model validation.

Algonquin Site Program Pine Study (ASP)

182 TSP's were established in the Pw cover types from Pembroke to Parry Sound District. These plots formed the basis for the Pine Forest Ecosystem Classification system developed by Merchant et. al. 1989. Detailed information on soil, site and other vegetation was collected.

Preliminary investigation of these plots indicate that some may be suitable for upgrading into the regional G&Y program.

Forest Health Plots

The Ministry of Environment and Energy installed a total of 110 PSP's across Ontario in 1986 to monitor the impact of acid rain on sugar maple stands. 49 of these plots were established in Central Region. Crown dieback was assessed and minimal mensurational information collected on these plots. Annual crown assessments have been performed. A potential partnership between the Ministry of Environment and Energy and OMNR (Forest Health Section and G&Y) is being developed to maintain this plot network.

Forest Land Productivity Survey (FLaPS)

The Forest Land Productivity Survey (FLaPS) was based on TSP's. The data collected included site information in combination with stem analysis sampling.

Numerous Stem Analysis Projects (Mh, By. Bw, Pr, Pw)

Various projects included a stem analysis component to their sampling methodology. The range of species sampled include, Mh, By, Bw, Pr and Pw. The data originated in various forms and on various computer hardware. A project was initiated to transfer all collected data to an IBM compatible format to allow for easier data manipulation and summarization.

Beckwith Research Plots

Nine Pr plantation plots were established in 1949. Four have had 6 remeasurements and 5 have had 3 remeasurements. Thinning treatments have been performed on 7 of the plots. Two remain as controls.

Thirty-three Mh dominated plots were established between 1968 and 1970. All have had a minimum of 3 remeasurements and some plots 5.

All data sets will be remeasured but will not be upgraded to new G&Y standards. Their long-term value will be in providing independent data sets for the validation of existing and newly developed models.

District Permanent Sample Plot Projects

Records of district PSP and TSP plot installations will be sought. Each installation will be evaluated for its applicability to the regional program. Every attempt will be made to incorporate the information.

In each case, plot records have been, or will be, sought; standards of data collection determined, and applicability of the data or plots determined. In many cases, plot networks have been determined to be appropriate for updating to current minimum standards, or at a minimum, a subset chosen for upgrading. Other plot systems have been found to be scientifically compromised to some degree and will either be abandoned by the regional G&Y program or measured solely for a model calibration data set.

Stem analysis data sets that have been collected for various projects have been catalogued. Maximum use of this destructively collected data (SI, back projection of stem growth), will be made before additional trees are felled. In most cases, excellent site description data is included with the stem analysis data.

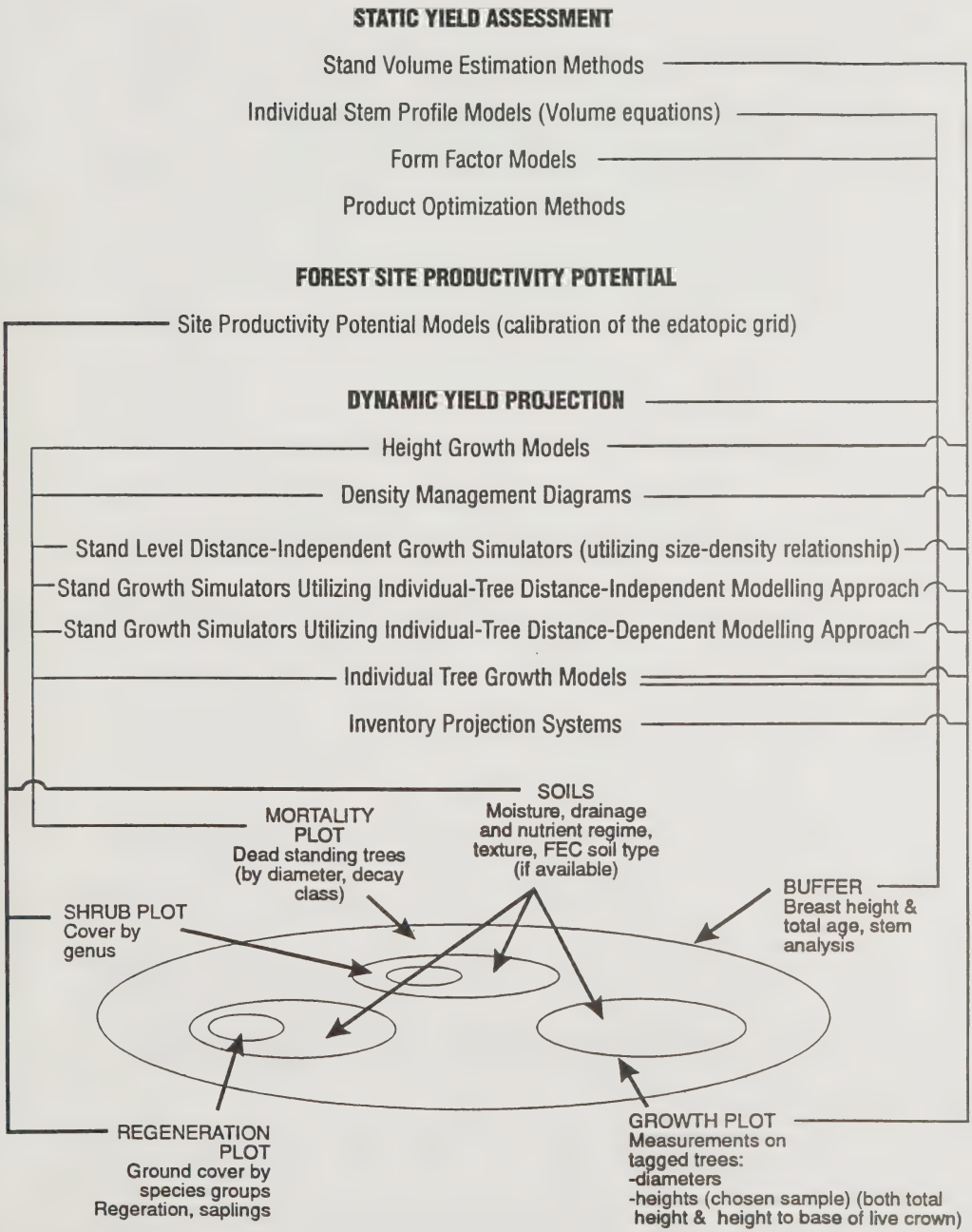
Projects that were installed using TSP's provide useful information on cover type/site associations useful to PSP establishment.

6.0 Regional Modelling Framework

The Central Region modelling framework follows "The Provincial Modelling Plan - A Framework for the G&Y Initiative" (OMNR 1992) for its direction. Figure 5 illustrates the linkages between the data collection methods employed and the final use of the data in the development of tools and models. As the G&Y Initiative is only one of many programs involved in resources modelling, emphasis must be placed on linking (regionally and Provincially) compatible efforts into modelling systems. Provincial programs such as the Ecological Land Classification (ELC) and VMAP program provide critical information in site categorization (relative productivity) and early stand growth. Future efforts in successional modelling by the G&Y program, or others, should continue to build on this developing foundation.

Simulators (models) that are developed either through the G&Y initiative or through co-operatives with other regional program initiatives will be developed in a "Modelling Task Team" approach. This task team will be made up of field practitioners (people who desire the simulator and are able to describe its format), G&Y program representative, regional

Figure 5. Modelling and Data Collection Linkages



program personnel (Hardwood, Conifer, VMAP, Forest Habitat, Systems, etc.) and modelling experts.

Cooperative efforts with the other regional G&Y programs will be sought when shared forest cover type models are being investigated or developed.
The regional modelling framework outlines the objectives and potential products of the Provincial and regional modelling program. It's being included with the intent of identifying where current regional needs fit within the framework. The prioritization of the modelling needs is identified in Section 6.2.

Sections extracted from: "The Provincial Modelling Plan - A Framework for the G&Y Initiative" (OMNR 1992) are *italicised.*

The general objective of the modelling effort is to produce reliable models for:

1. *Stand growth projection and dynamics, and*
2. *Yield Assessment.*

The framework for forest modelling is based on the following principles:

1. *Understanding of the object being modelled within natural constraints,*

2. *Recognising where and how the model is to be used (i.e. ecosystem management objectives, economic constraints),*

3. *Knowledge of the predictive power and limitations of existing models as well as knowledge of all modelling approaches and methods, and*

4. Timely and economically efficient delivery of models to identified users.

6.1 Potential Modelling Products

1. *Static Yield Assessment Methods and Models*

   a) *Stand Volume Estimation Methods are used to estimate stand volume in support of cruising methods (groups or classes of individual tree diameters or heights). Models and methods in both conifer and deciduous stands will strive to minimize the need for laborious measurements, such as height measurements.*

Stand volume estimation methods needs to be standardized are needed for the commercially important trees species within the Central Region. Presently, districts and local industries are applying different estimation methods for the same species of trees. This approach particularly causes problems when industries are dealing with neighbouring districts and areas. The results of these methods must also be supported by reliable local tree volume estimates.

Further refinement of the ITAWCRUZ program by incorporating a standardized data collection and data storage procedure by forest cover type will allow the exchange of cruise data between resource managers (i.e. geneticists, wildlife biologists, etc.).

b) *Models Supporting Stand Volume Estimation Local Total Tree Volume Equations, Form Factor Models, Individual Stem Profile Models (by species) are used to provide accurate volume estimates for any required part of a tree stem.*

The proper use of the partial-harvesting silvicultural systems used regionally, requires present and future stem quality estimates. The opportunity of removing poorer quality stems, and leaving to grow or regenerate, higher quality stems, is a key management decision of the marking system. Currently, only hardwoods are assessed for stem quality. The development of a quality assessment system, in conjunction with a potential forest product classification system for species suited to partial cutting systems, is needed.

This requires:

- Development of methods to determine stem quality from simple field observations;
- Local individual total and merchantable tree volume equations;
- Locally valid descriptions of tree form factors, as well as,
- Models able to provide volume estimates combined with a product quality evaluation.

c) *Product Optimization Methods are for individual standing trees and stands. The models are used to account for different economic scenarios (i.e. consideration of product dimensions and prices).*

This type of static model works well with coniferous species but is less practical in the highly variable deciduous forest types. Although not a high priority modelling issue at this time, methods of product optimization will need to be developed.

d) *Inventory Projection Systems are methods that provide efficient use of ground measurements and remote sensing for stand volume estimation and projection.*

The development of this modelling area should complement the methods of stand volume estimation. There is a need to estimate standing volume and potential quality of existing stands more economically and on a broader scale with funding for future stand inventories becoming less available.

These models are required to predict species composition, stand structure, stocking, cavity supply and down-woody-debris for timber and habitat supply models.

2. Site Productivity Models

Evaluating the production potential of a forest site is crucial for modelling forest dynamics. Because the biotic elements of a site influence the abiotic growth conditions over time, site production potential will be defined by:

a) the potential presence of tree species, and
b) the growth and vigour of the biotic and abiotic components, in relation to each other, stemming from ecological adaptation.

Each potential productivity model should hypothesize successional trends for specified strata. These models will utilize and link to all advancements in ecological site classification in Ontario, as well as recognize forest genetic growth components.

"Site modelling" requires a comprehensive evaluation of the forest site within a complex hierarchial system. For the G&Y initiative, the order is: province; ecological regions (ecoregions); forest site types of specific moisture/nutrient regimes (edatopic grid); individual tree growth environment (micro-site).

The need for "site modelling" approaches is apparent with some of the modelling issues identified. They include:

- refining the ecological stratification forest cover types for sampling;
- calibration of the edatopic grid (COFEC productivity relationships); and,
- preliminary forest succession models.

Past work on this for the Central Region includes the work of G.A.Hills (1959) A Ready Reference to the Description of the Land of Ontario and its Productivity , Heikurinen, J.K. and H.M. Kershaw, Forest soils as a Management Framework (1986) and Merchant et. al. (1989) Pine Forest Ecosystem Classification.

The Central Region G&Y program desires a continuation of the investigation of the relationships and attempts to quantify some of the key productivity/site questions that are at the foundation of site stratification.

3. Dynamic Yield Projection Models

Traditionally, G&Y information has been presented in the form of:

1. G&Y tables
2. G&Y equations
3. G&Y simulators.

All of these forms have dynamic features and have been used for predictive purposes. Predicting the dynamics of the forest tree and stand is the ultimate goal of the G&Y Initiative.

a) *Height Growth Models (Site Index Curves) are required for all* even-aged *modelling efforts. These models can estimate site productivity for species which have not been influenced by non-site factors such as density or stocking. In other words, it is an estimate of the maximum growth that a species can achieve on that particular site.*

The development of site index curves for Central Region's commercial species is a high priority. Models that have been developed outside Ontario and that will be developed within the Provincial modelling framework (including density management diagrams) will rely on a site index estimate as an indicator of potential site productivity. Current use of site index values developed for the same species in the United States may or may not be valid. Validation of these curves will be necessary to ensure that similar patterns of growth occur in the differing physiographic and climatic zones.

b) *Density Management Diagrams are simple, average stand models that represent dimensional relationships in graphical form. They are most applicable to managing plantations, and will aid in site-specific decisions regarding stocking.*

Central Region has an abundance of conifer plantations in red pine, white pine, jack pine and white spruce. A tool such as density management diagrams (DMD) can be useful in managing their growth and development towards specific end products. Work has been initiated on DMD's for the province, with emphasis thus far on jack, red, white pine, black spruce and trembling aspen. Expansion of the effort across the range of appropriate species and regions, along with combining the diagrams with site index productivity gradients, is a high priority.

c) *Stand Growth Simulators utilising either the Individual Tree, distant-dependent or distance-independent approach, are classes of models which describe the interrelationships between individual trees growing in a stand.*

The initial stand growth simulators developed for Central Region species will be ones developed as diameter class type models. With further refinement and increased levels of expertise, the development of simulators will move towards the more desirable Individual Tree, distant-independent class of simulator. The high-value species (and therefore, products) produced in this part of the province require that individual quality attributes be considered in the modelling process.

Most simulators will be designed to predict growth or yield and tree or stand quality over time by treatment options, while considering other ecosystem values (habitat, aesthetics, etc.). These types of models are of great value for modelling wildlife habitat. Estimation of snag decay class, cavity trees and down-woody material attributes will supplement the usefulness of the model. The simulator should allow aggregation from the tree to the stand, and finally, to forest levels.

With these tools forest managers will be able to forecast impacts of stand and forest level management activities on wildlife habitat and allow for the evaluation of current habitat guidelines and aid in the development of new ones.

Basic inputs to the simulator should involve variables already collected by field staff using ITAWCRUZ /COFEC systems. To provide the most realistic simulation, the list of variables should include:

Stand Data
- site information
- silvicultural history
- location
- Area of Concern (AOC) history
- habitat values (snags, down-woody debris)
- vegetation list (or COFEC vegetation type)

Tree Data
- species
- dbh
- quality/decay class
- crown position
- clear bole length
- tree height
- cavities

Additional variables (i.e. crown radius) can be added if precision of simulator (for the stated modelling objective(s)) is greatly improved.

The simulator should have the following capabilities:

- be user friendly (help facility);
- allow user-specified simulation intervals;
- check for inappropriate data values (including missing values);
- depletion strategies under user-control (marking strategy);
- algorithm for mortality and recruitment;
- algorithms for change in tree quality and crown class;
- calculate periodic growth (by summation or differences)
- sensitive to quality and merchantable length;
- sensitive to competitive position (crown class);
- sensitive to habitat values (den trees, snags);
- allow for product optimization (veneer, sawlog, pulp); and,
- modular design to allow calibration, addition of future process-based modules (i.e. climate change, CO^2 flux, and others)

The outputs should provide the resource manager with information that will assist in strategic, managerial and operational aspects of the job. The products include:

- simulated stand and stock tables by species, dbh class and quality class for a chosen growth interval and size-class groupings;
- tabular or graphical output format choices;
- the ability of performing "what if" scenarios; and,
- product selection/optimization abilities.

The evaluation and calibration of existing stand growth simulators is a high priority requirement of this region. If an existing model (i.e. TWIGS, STEMS (within INFORM), SILVAH, FIBER or STIM) can be inexpensively validated or calibrated to meet short term needs, it will be pursued.

4. Individual Tree Process Growth Models

These types of models will be developed to support stand growth simulators and address ecosystem issues at the individual tree level. It will include the modelling of the relationships between tree crown growth and diameter growth, lateral rate of crown expansion and other variables.

The area of Individual Tree Process oriented growth models (or hybrids of empirical and process models) are a class of models which require long-term attention. The understanding of impacts of environmental attributes on individual tree growth is more realistic then modelling future growth conditions based on past growth characteristics.

However, model developments in this area are a much lower priority than other empirical approaches.

6.2 Modelling Priorities

The modelling priorities of Central Region G&Y program are the identified needs of resource managers of the region.

The priorities of model development are :

1. **Development and Validation of Local Volume Tables for all Commercial Tree Species.**
   Few volume tables have been constructed and validated for Central Region species or growing conditions. Many tables used now have never been validated to ensure that the are adequately representing the species. The development of local volume tables will allow OMNR and Industry to use the same information independent of district and area boundaries.

2. **Development of Density Management Diagrams for Even-aged Stand Conditions.**
   The development of density management diagrams for Central Region's even-aged monoculture stand conditions is a high priority. This tool will assist resource managers in making decisions on: modifications to present stocking conditions (i.e. thinning), or initial density levels to meet specific target end products. DMD's are currently being completed for red pine, white pine, jack pine, black spruce and trembling aspen.

3. **Development of Site Index Equations or Diagrams for Commercial Even-Aged Species.**
The development of Site Index equations and diagrams for even-aged species is required for the quantification of productivity gradients on Central Region sites. In addition to the equations and diagrams alone, the development of a field implementation methodology assuring unbiased estimates is required. Site Index will provide a productivity driver for all even-aged models (including density management diagrams) that will be developed by the G&Y program.

4. **Standardization of ITAWCRUZ Forest Cover Type Sampling Methodology for Operational Cruising in Central Region.** The ITAWCRUZ data collection and summary cruising model is operational in Central Region. Presently, certain stand attributes (i.e. height) collected by the program are optional or at the operator's discretion. The option to collect, or not, data attributes has been viewed as a great convenience by the users, as certain forest cover types being sampled are more difficult than others. Unfortunately, the lack of these more difficult attributes means that the data collected is less transferable to other potential users.

   Instead of requiring all attributes (or equal observations) to be collected before data collection can continue, it is suggested that the data collection procedure be optimized to minimize the total number of observations, or list of attributes collected (e.g. only 5 heights instead of 15) depending on the forest cover type being sampled. This enhancement of the program will allow data summarization to be presented at known error levels. In addition, data that is collected, say in Pembroke district in an uneven-aged hardwood stand can be pooled or compared with data from a similar stand condition in Sault Ste. Marie district for a timber or multi-use purpose.

5. **Development of Standardized Fact Sheet Summary and Reporting System for all PSP's established in the Region.** For each PSP established in the region there is a current yield estimate, vegetation summary and site description. The development of a fact sheet for each plot is viewed as a convenient method of transferring information immediately from this long-term investment. Resource managers can utilize the fact sheets of PSP's in their areas for estimating standing volume, wildlife habitat availability, etc..

   The digital PSP fact sheet summary will also become part of a data set available to all potential users of tree and stand data. This "Modelling Data Library" will allow users to search for plots meeting their criteria and extract either tabular or graphical summaries.

6. **Evaluation and Calibration of Suitable G&Y Models for use in the Central Region.**
There are many excellent models available to the resource manager that have been developed in this country and in others. Many of the models are readily transferable to our forest conditions. Unfortunately, with their application comes an unknown error level. **For the short term,** Central Region would like to have existing models

evaluated (benchmarked) for use in the region. Appropriate modelling approaches should then be calibrated for growth conditions (with expressions of error) in the region.

Details such as availability of the models' programming source code and cost should be rated in the evaluation stage of the model. These models are not intended to be the models of the future, but rather, ones that will bridge the gap for resource managers until models developed in Ontario are operational.

7. **Refinement and further Development of a Managed Tolerant Hardwood Model .** Work was initiated in the mid 1970's on the development of a silvicultural model for the tolerant hardwood species (mainly hard maple stands) in the old Algonquin Region by the Research Branch. Remeasurements of the PSP's have taken place regularly. A preliminary model was developed in the mid 1980's based on the data. Several theories within the model require updating and validation. Routines established for mortality functions require calibration. Advancements in computer and software capability will now allow the model to be refined and further developed to satisfy todays requirements. This model, as well as other existing models from the United States, will be tested for suitability to Ontario's conditions and requirements (linked with priority 6).

8. **Calibration of the Edatopic Grid (COFEC Productivity Relationships) .** A requirement of preliminary modelling efforts is the calibration of the edatopic grid. The theoretical relationship between the nutrient/moisture status of a site and the potential productivity, relative vigour of growth and ecological equivalence, requires quantification prior to plots being aggregated for future modelling. The use of the COFEC site types may provide an operational linkage to the identification of common units.

9. **Expansion of stem quality assessment for all commercial forest species.** Central Region utilizes the hardwood quality classification system (developed for the Algonquin region) for the tolerant hardwood species. Because stem quality is an issue for the majority of the managed commercial species in this region, the expansion of the assessment system to conifers and intolerant hardwoods is logical.

   The assessment system developed should look at the present quality and future quality of the stem based on health, vigour and other factors. A *"timber-only"* consideration should be minimized by developing the quality class system independently of *"merchantability"* concepts.

10. **Development of Models that can Simulate G&Y, Quality of trees or stands, recruitment rates of cavities and recruitment or decay rates of snags and down-woody debris for Central/Southern Forest over Time by Management Options.**
    Central Region's resource managers require the development of Ontario models to provide aid resource management in a sustainable manner. The simulators or models developed should meet all the criteria outlined in Section 6.1 (c). They must be aggregatable at different levels (tree or stand or forest). Examples of scenarios to be

simulated include: If the stand is depleted to a certain level, what impact does this have on habitat suitability for ungulates? What will the stand look like to hikers? Can this stand respond to this level of harvest and provide an additional harvest in 20 years? What type of scarification would be needed to promote the establishment of ....? How does stand intervention of this type affect the wildlife of neighbouring stands?

The development of these models will take time. Modellers will develop them step by step. Modules developed by different modellers should fit into larger modelling frameworks.

11. **Refinement of the Forest Cover Types for Central Region to Aid in Sampling Efforts.**
The Central Region G&Y program sampling is based on forest cover types developed and refined for program implementation. Our knowledge of these cover types expands as the species components of each plot are analyzed. This knowledge, combined with the developing site type matrix of COFEC, will allow us to refine or modify the cover types to more valuable units of ecological description.

12. **Development of Forest Succession Models.**
Althoug not an immediate high priority, the need for these types of models in the near future exists. With the completion of work at the tree and stand level, modelling work should focus on the forest level. Initial work should concentrate on the prediction of changes in species composition and stocking. Ultimately, we require models to predict changes in overstorey and understorey composition and forest structure.

The development of Forest Succession Models based on PSP's is a long-term focus of the G&Y program. Initial attempts at developing immediate successional information may be based on interpolated development of chronosequenced sets of PSP records.

6.3 Modelling Responsibilities

Co-ordination of Ontario's modelling framework is the responsibility of the Forest Modelling and Productivity Program (FM&PP) within the Ontario Forest Research Institute. This program is responsible for developing a user-friendly system (framework) which houses appropriate G&Y simulators developed within OFRI and elsewhere. All simulators will allow for common input sources and provide common output summaries. Simulator output summaries will be verified and validated at known error levels. The FM&PP in OFRI is a source of modelling expertise for the needs of the province. Models developed within the G&Y program will benefit from OFRI modelling expertise.

The responsibility for model development rests within several program areas of the OMNR and other agencies (provincial researchers, federal researchers, private consultants). Main office, Science & Technology Sections and other organizational units of the OMNR

structure have the expertise to perform some modelling tasks. Central Region has G&Y modelling expertise available within the Regional Planning and the Science and Technology Sections that will be used to fulfil some of the modelling needs of the region. Other modelling needs may involve the use of external modelling consultants. In these situations, Central Region may use the FM&PP to facilitate/screen the development or contracting of suitable professionals to perform the task.

Models developed outside the FM&PP for the Central Region G&Y program must meet the data input and output standards set by the Provincial Modelling Framework. Validation of the model will be performed in accordance with standards documented by the FM&PP.

7.0 Communication

Long-term survival of the G&Y program depends on good communication. A program that is based on PSP's has the ability to provide sound answers to questions many years in the future. The challenge faced by the G&Y program is to communicate the program's methods, scientific soundness, short term products and long-term benefits.

The responsibility for communication falls to all involved with the program. The program leader to the field plot establishment staff should all be capable of discussing the programs objectives and methods with anyone. Direct contact with field resource staff, small group discussions or larger group presentations continue to be the most significant forms of communication. Feedback on priorities and needs from resource managers are incorporated quickly into the program. More indirect methods, such as poster displays, are utilized to inform interested conference participants about the program. This form of communication stimulates discussion by interested people.

Opportunities to communicate with and educate resource management students will continue to be a high priority of the Central Region program. The development of technically skilled individuals educated in methods standard to the G&Y program benefits the program as well as the future public and private sector forest agencies. The willingness of educational institutions to update curricula, in terms of equipment and techniques, for their students employment benefit, has been excellent.

7.1 Landowner Information Package

Nineteen percent of the productive forest land in the Central Region is private land, predominantly in the southern districts. Filling the sampling matrix will require the establishment and monitoring of PSP's on some private land. In other instances, land owners have approached the OMNR and requested information be gathered (and passed back to them) on their woodlots.

A landowner Information Package (Figure 6) has been prepared (in co-operation with the Southern region G&Y program) which provides a layman's overview of the program and answers some of the more commonly asked questions. What has become apparent in dealing with some of the landowners is the variety of interests and objectives they have for their

Figure 6.

A LANDOWNER'S GUIDE

to the

CENTRAL ONTARIO FOREST GROWTH AND YIELD PROGRAM

Central Region
Growth and Yield

NODA·EDNO
CANADA ONTARIO
Northern Ontario Development Agreement
Entente de développement du nord de l'Ontario
Forestry • Foresterie

Natural Resources Canada / Ressources naturelles Canada
Canadian Forest Service / Service canadien des forêts

Ministry of Natural Resources / Ministère des Richesses naturelles
Ontario

GROWTH AND YIELD: A LANDOWNER'S GUIDE

In 1992 the Ministry of Natural Resources (MNR) established a Sustainable Forestry program. The aim of this program is to improve the way in which the resources of this province are managed. The goal of our efforts is to recognize the value of the resources, and manage them in such a way as to provide for current and future demands. This is known as sustainable forestry. This not only applies to activities such as timber harvesting and hunting (consumptive), but to other activities, such as recreation and wildlife viewing (non-consumptive).

With regard to forest management, the MNR is planning to establish long term growth and yield plots. These plots will be set up to allow MNR staff to collect data on the entire forest community or ecosystem- from the obvious (trees and shrubs) to the not so obvious (soils and wildlife habitats). The basis of this program is the creation of a series of Permanent Sample Plots (PSP's), in a variety of ecosystems found throughout the Province. These include hardwoods, conifers, plantations, and so on.

Some unique forested areas in Central Ontario are privately owned. In order for this program to be successful, it will be necessary to locate many of the PSP's on private land. The following are some of the questions commonly asked by landowners interested in becoming involved in the

JUST WHAT IS A PSP?

A Permanent Sample Plot (PSP) is a representative area in the forest ecosystem with set boundaries. In this program, the plot will be circular, and cover 0.6 hectares or 1.5 acres. The area will be clearly marked, using a central post, to ease in future location of the plot, and to ensure that data collection methods are consistent. A PSP is the preferred method of gathering data because it allows managers to observe changes over time in a set area. The data will be quantitative (factual, such as measurements) instead of qualitative (based on the feelings and views of the person doing the field work). Data collected in 10 years can be directly compared to data collected this year. This data will give managers a glimpse at some of the changes that occur in a forest ecosystem.

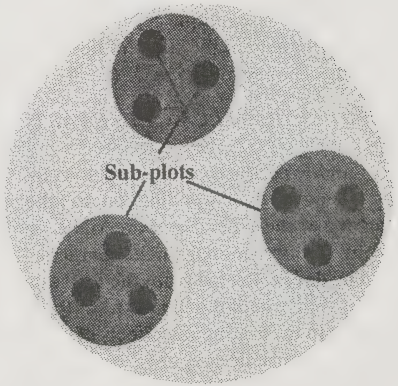


Illustration of a Permanent Sample Plot. Each PSP consists of sub-plots to measure mature trees, regeneration, shrubs, and plant species.

WHAT KIND OF DATA WILL BE COLLECTED, AND HOW OFTEN?

Managers will be collecting data on soils; the types and numbers of ground plants and trees; height, diameter, and age of trees; and the overall health of the ecosystem. Over the years, managers will continue to collect this data, comparing it with data collected in the past, to determine how different forest ecosystems change with time. It is anticipated that data collection will occur every 5 to 8 years. If major changes are expected, such as thinning or other forest operations, then before and after data can be taken.

WHAT WILL MNR DO WITH THIS DATA?

Managers will use this data to predict the future development of naturally occurring, planted and managed forests to assess and maintain these unique ecosystems. The data will also help in the study of how these ecosystems change over time.

DOES THIS MEAN I CAN'T USE PART OF MY WOODLOT?

Landowners are encouraged to continue managing their woodlot and, to take advantage of the expertise of the MNR, or its many resource management partners.

The data collected from the PSP established in your woodlot will assist MNR managers in evaluating the effects of various management practices.

Some PSP's will be established in areas where there will be no human disturbance. These PSP's, known as baseline plots, will provide information on how the forest ecosystem changes naturally over time. They will likely be set up in Provincial Parks and other areas owned by the Province.

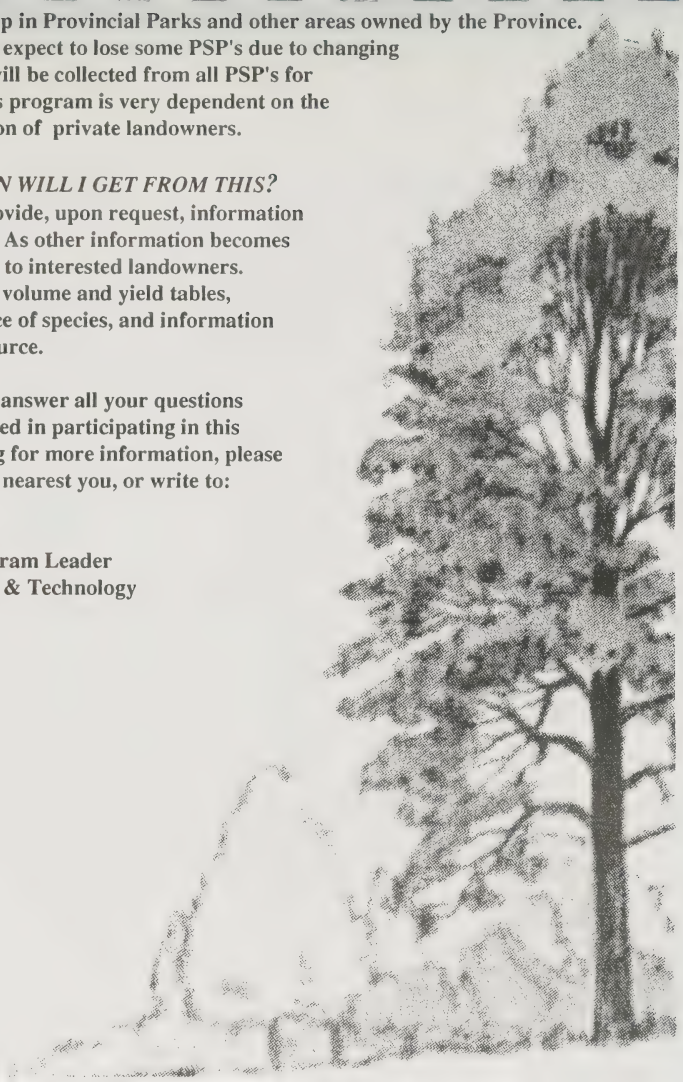
Project managers expect to lose some PSP's due to changing land ownership. Data will be collected from all PSP's for as long as possible. This program is very dependent on the goodwill and cooperation of private landowners.

WHAT INFORMATION WILL I GET FROM THIS?

Managers will provide, upon request, information on the forest inventory. As other information becomes available, it will be sent to interested landowners. This may include wood volume and yield tables, trends in the appearance of species, and information on the value of the resource.

It is impossible to answer all your questions here. If you are interested in participating in this program, or are looking for more information, please contact the MNR office nearest you, or write to:

Murray Woods
Growth and Yield Program Leader
Central Region Science & Technology
Development Unit
P.O. Box 3070
North Bay, Ontario
P1B 8K7



property. These range from nature retreats, maple syrup production and small fuel wood cuts, to full scale harvesting options. Landowner forest resource philosophies, in some cases, are a factor in determining the ineligibility of a woodlot for PSP establishment.

Some landowners are not willing to allow any sampling which may or will cause the loss of a tree (i.e. increment coring or stem analysis). The opposite is also true. Some landowners have total resource extraction planned as the only management option for their landbase and see the G&Y program as providing a volume estimate for their woodlot. In either case, the establishment of a PSP may not be in the best interest of the G&Y program.

Landowners willing to implement scientifically sound management practices will enter into a landowner contract to provide some long term protection for the plot. A total harvesting moratorium on the plot area will not be the only contract option. If the landowner is considering a harvesting operation in his woodlot (improvement or commercial), the G&Y program would like to participate in having the stand marked for cutting.

7.2 Permanent Sample Plot Fact Sheet

Identified as a Central Region modelling priority (see Section 6.2 - 5), the permanent sample plot fact sheet is a method of providing immediate information on forest cover types being sampled. This information which is not intended to replace cruising or ground surveys is aimed at providing resource managers with information on the variation of factors such as structure, basal area, volume, of local cover types. In addition, the fact sheet provides summaries useful to the program in maintaining records of sampled matrix cells and historical documentation.

The digital summary information generated for the PSP fact sheet will form part of the Provincial "Modelling Data Library". Modellers (G&Y and other interests) from the OMNR and elsewhere will have access to this database and the ability to screen possible PSP data sets for modelling purposes.

8.0 Research

Research is critical to the long-term success of the G&Y program (OMNR 1992). The Central Region G&Y program, in conjunction with the Provincial program, or alone, will use, facilitate and support research and development in the many facets of G&Y.

Collaboration with Provincial research institutes, Federal research centres, universities and private consulting organizations will be sought to meet research needs.

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Appendix A - Minimum Standards For Permanent Sample Plots

Extracted from - A Master Plan to examine forest growth and dynamics in Ontario.

May 1993

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LIST OF TABLES

1.0 SCOPE OF THESE STANDARDS

These standards set out the minimum criteria to be used for the establishment and remeasurement of permanent sample plots (PSPs) forming part of the Ontario growth and yield program. The data collected is intended for the development and maintenance of forest growth, yield and productivity records for Ontario. These records will be kept and maintained in a provincial database.

2.0 PLOT LOCATION, ACCESS AND PROTECTION

2.1 Plot Location

Each plot must be located and identified on the latest available Forest Resource Inventory map and aerial photo. The map title, date of inventory production, and stand number within which the plot falls must be recorded. The plot location must be recorded as accurately as possible by noting either the UTM coordinates or the latitude and longitude to the nearest degree, minute, and second. The preferred method of obtaining latitude and longitude is by a global positioning system device.

2.2 Plot Access

Routes and distances must be mapped and described in detail, from an easy-to-find starting point that is unlikely to disappear, to a permanent landscape feature or well-marked temporary feature. Distances between features such as road junctions, creek or river crossings, bridges and others must be noted. Azimuth and distance from the permanent landscape feature or well-marked temporary feature to a plot corner must be recorded accurately. The access description must be updated at the time of plot remeasurement if access has changed.

2.3 Plot Protection

Plots must be protected from vandalism, trespass, road building, mining, logging and other types of man-caused damage. All growth and yield PSPs should be identified on District values maps, and District and Company staff should be notified in writing of the exact location of each PSP and the value it represents. All growth and yield PSPs that fall within operating areas of a Timber Management Plan should also be identified as Areas of Concern, and assigned an appropriate prescription (see Section 2.5, Plot Silvicultural Treatment) to protect them from operational activities. All growth and yield plots should be identified on claim maps at the Mining Recorders office.

2.4 Plot Buffers

A buffer area is required from the plot to the edge of any major local disturbance (logging, road building, agricultural land etc). An area must also be set aside directly around the plot that receives the same management regime as the plot itself (e.g. spacing, thinning, fertilization, pesticide application). The width of this marked or

flagged buffer treated like the plot must be at least 20 m or equal to the expected mature height of the dominant trees in the stand, whichever is greater.

2.5 Plot Silvicultural Treatment

When plots are to receive silvicultural treatments as part of the growth and yield program, the following applies:

- plots must be established and measured before the treatment in order to quantify initial conditions;
- the type and date of treatment must be recorded as follows: commercial thinning; non-commercial thinning; cleaning; cull tree removal; pruning; sanitation cut; manual spacing; herbicide tending; pesticide tending; fertilization; site preparation; or other treatment type.
- plot buffers must receive the same treatment as the plot;
- plots must be measured in the same season that they are treated; and
- after thinning or spacing, the residual stems on the plot must be verified.

3.0 PLOT LAYOUT

3.1 Standard Plot Size and Shape

A PSP for growth and yield consists of a large circular plot, or stage-one sample unit, with a minimum area of 6400 m^2. This stage-one sample unit will be used to sample tree mortality.

Within this mortality plot, a minimum of 3 stage-two sample units will be selected for sampling. Each stage-two sample unit will be located at a weighted, randomly selected distance from the stage-one plot centre. The stage-two sample units will be located on radii spaced 120 degrees apart, with a randomly selected first radius. These sample units will be used to sample individual tree characteristics. They will be circular in shape with a minimum area of 400 m^2 each.

Within each stage-two sample unit, or growth plot, a minimum of 3 stage-three sample units will be chosen for sampling the composition and density of shrubs, regeneration and vegetation. Each of these shrub/regeneration/vegetation plots will be located at a weighted, randomly selected distance from the stage-two plot centre. The plots will be located on radii spaced 120 degrees apart, with a randomly selected first radius. They will be circular in shape with a minimum area of 25 m^2 each.

The azimuth and distance from the mortality plot centre post to the centre posts of all growth, shrub/ regeneration/vegetation plots used in the standard plot design must be measured accurately and recorded.

3.2 Square or Rectangular Plot Design

While the majority of growth and yield PSPs in Ontario will be circular plots, in exceptional circumstances the use of square or rectangular plots may be more efficient or appropriate. Where square or rectangular plots are used, the stage-one sample unit or mortality plot will consist of a large square or rectangular plot with a minimum area of 6400 m^2.

The mortality plot will be subdivided into a minimum of sixteen equal stage-two sampling units, with a minimum area of 400 m^2 each. At least 3 of these will be randomly selected for sampling as growth plots.

Each growth plot will be further subdivided into a minimum of 16 stage-three sample units, with an area of 25 m^2 each. No less than 3 of these will be chosen for shrub/regeneration/vegetation sampling.

For all plots used by the Ontario growth and yield program, the shape, dimensions, number and location of all mortality, growth, shrub and regeneration plots used must be determined accurately and recorded.

3.3 Reduced Growth Plot Size

In growth plots such as young plantations where there are, or are expected to be, a large number (more than 200) of trees greater than 2.5 cm dbh, a reduced-size growth plot may be installed. Two different methods may be used to install reduced-size growth plots. However, within a single mortality plot only one reduced-size plot installation method may be used, with the same reduced-size plots in all growth plots.

A reduced-size plot may be installed in plantations by installing only the center stakes of each growth plot. The three shrub plots within each growth plot will then be used as reduced-size growth plots, with tree numbering, diameters, and heights and all other growth plot measurements carried out only within the area of the three shrub plots. The reduced-size growth plot will be expanded to the full plot size when the number of trees greater than 2.5 cm dbh within the reduced plot (shrub plots) falls to less than 50 trees.

Reduced-size plots may also be created by installing a single smaller plot within the growth plot, either as a quadrat of the full size growth plot or as a smaller radius circle within the full plot area. This reduced-size plot may have an area of 50, 100 or 200 square metres, and will contain a minimum of 100 trees greater than 2.5 cm dbh (or trees expected to reach 2.5 cm dbh, in very young plantations). Tree numbering, diameters, heights and all other growth plot measurements will be carried out only within the area of the reduced-size plot. When a reduced-size plot of this type is

installed, the full growth plot boundary must also be laid out, and all trees within the full boundary must be counted, by species, at the time of measurement or remeasurement. The reduced-size growth plot will be expanded to a larger plot size, and eventually to full growth plot size, when the number of trees greater than 2.5 cm dbh within the reduced-size plot falls to less than 50 trees.

3.4 Other Plot Sizes

The majority of plots in the Ontario PSP network will adhere to the minimum sizes as defined above. However, in exceptional circumstances where conditions warrant (such as with existing plots incorporated into the PSP network), smaller plots will be installed or the plot design will be changed so that a modified growth and yield plot may be placed where it would not otherwise be possible to locate a complete standard plot.

3.5 Plot Posts

For standard circular plots, permanently mark the centre post of each mortality plot and growth plot. Indicate the position of each growth plot centre post relative to three tagged trees, including azimuth and distance.

For square or rectangular plots, permanently mark each corner of each mortality plot. Indicate the relative position of each growth plot corner post to three tagged trees (section 6.2), including azimuth and distance.

At the time of remeasurement any missing corner or centre stake in mortality or growth plots must be relocated and reinstalled. Although shrub and regeneration plots need not be marked in a permanent manner, it is suggested that some form of permanent marker, such as regeneration assessment pins, be used to make these plots easier to find for remeasurement.

Program identification information tags must be placed on all road posts, mortality plot posts, and growth plot posts. In circular plots, the tags are attached firmly to the center posts, while in square plots the tags are attached to the southwest corner posts. Information required on each tag includes growth and yield program identification, identification of the post type, the Permanent Sample Plot number, and appropriate plot distance information (see above).

3.6 Plot Buffer Marking

The outside of the buffer area around each PSP (see Section 2.4, Plot Buffers) should be well identified and marked. At a distance of at least 20 m outside the mortality plot boundary, paint a large *red* dot at breast height on as many trees as necessary to insure complete plot visibility. Place the dot on the side of the tree that faces away from the plot.

4.0 SITE, SOIL AND ECOLOGICAL DESCRIPTION

4.1 Site Description

The average plot slope gradient must be recorded to the nearest percent. The position of the plot on the slope and/or plot topography must be described as follows: ridge crest; upper slope; middle slope; lower slope; toe; depression; level or flat; or rolling. The plot aspect or average compass point faced by the slope must be recorded in azimuth to the nearest degree. Plot elevation must be recorded to the nearest 25 m (preferably using a global positioning system device - this will be a standard after 1992).

4.2 Soil Description

During plot reconnaissance, a minimum of one soil auger sample per growth plot selected must be taken to a minimum depth of 120 cm or to bedrock, and its description recorded, in order to assess soil conditions and determine the representative soil type for the plot. When necessary to describe the soil variation within each growth plot, two soil auger samples must be taken and recorded at positions representative of the primary and secondary site conditions within the growth plot area. The surface humus form and each soil texture (or degree of decomposition in organic soils), along with any soil mottling or gleying present and the depths to each must be recorded for each auger sample. Moisture regime and drainage class must also be calculated for each auger sample. The positions of auger samples and all site conditions encountered must be mapped for each growth plot.

At the time of plot establishment on relatively uniform sites it is suggested that a standard soil pit be excavated and described. This pit should be dug in a part of the destructive or non-destructive sampling buffer area more than 10 m from a growth plot boundary that is representative of soil conditions on the three growth plot areas. Soil pits should be excavated and the pit and soil surface described according to *A Minimum Standard for Describing Forest Sites with a Soil Pit* (Pierpoint and Uhlig 1988), pages 4-13.

4.3 Ecological and Silvicultural Information

The mortality plot and each growth plot must be classified according to appropriate Forest Ecosystem Classification (FEC) criteria, if an FEC is available.

The stand origin or kind of disturbance will be determined and recorded as follows: fire origin; insect or disease origin; logging origin; windthrow origin; agricultural origin; other; or unknown.

The stand establishment method will be ascertained and recorded as follows: planted; natural; or artificially seeded.

The silvicultural system last used on the stand will be documented as follows: clearcut; strip clearcut; shelterwood strips; uniform shelterwood; block cut; seed

tree or group seed tree cut; harvest selection cut; or improvement selection cut.

5.0 PLOT STATUS INFORMATION

5.1 Measurement Schedule

Plots must be remeasured at least once every 10 years, but preferably at 5-year intervals. It is highly preferable that all plot tree height and diameter measurement be scheduled, where possible, either before bud flush in the spring, or after most of the current year's height and diameter growth has occurred, in the late summer or fall.

5.2 Measurement Date

The date of the completion of plot establishment and measurement, or plot remeasurement, must be recorded.

5.3 Current Status

The status of the plot at all measurements will be assessed and if disturbance is found, the degree of disturbance will be recorded and described. Plot status will be identified as follows: active; inactive or abandoned; lost; or destroyed.

5.4 Measurement Crew

Each field crew installing, evaluating or remeasuring a plot must record the names of its members on the plot tally sheet or data logger. The employer (including OMNR District, Region or main office), contractor or outside agency must also be noted.

6.0 PARAMETERS TO BE MEASURED - MORTALITY PLOTS

6.1 Standing Dead Trees

At plot establishment record the species (if possible), diameter at breast height (dbh*) and condition of all standing dead trees with a dbh greater than or equal to 2.5 cm (see condition class codes for dead trees, Table A1). Mark all tallied dead standing trees at breast height conspicuously and permanently with tree marking paint or by blazing. Any downed dead stems that appear to have fallen recently should be marked, but not measured, in a similar manner.

At each remeasurement record the condition of all previously marked dead trees. For all unmarked dead trees standing or fallen that have died since the last measurement, separately record the species, diameter and condition. Mark all newly tallied dead trees in the same manner as at plot establishment, and touch up the marking on all previously marked dead trees.

7.0 PARAMETERS TO BE MEASURED - GROWTH PLOTS

7.1 Breast Height Identification

At plot establishment, breast height will be measured at 1.30 m above the base of each tree on the uphill side, on all living trees in each growth plot. Mark all living trees of a dbh greater than or equal to 2.5 cm in a permanent manner at breast height with tree marking paint, silicone caulking, or tube paint. The breast height point of measurement will be adjusted, and the adjustment recorded, if breast height occurs at a branch whorl, swelling, or other abnormality.

7.2 Tree Marking and Numbering

In each growth plot, all living trees greater than or equal to 2.5 cm diameter breast height (dbh), and all standing dead trees greater than or equal to 2.5 cm dbh must be labelled and numbered individually and uniquely with a permanent tree number. Mark tree number in a permanent manner above breast height with tree marking paint, silicone caulking, or tube paint, or just below dbh with a metal tag (on trees greater than 10 cm dbh only). Marking just below dbh with rustproof or aluminum nails and a metal tag may not be appropriate in some areas, because the nails may then constitute a safety hazard to cutters or sawyers if the tree is cut down.

7.3 Tree Diameter Measurement

Measure and record the dbh of all living, numbered trees and recently dead, numbered trees to the nearest millimetre with a metric diameter tape. Do not record the diameter of any dead tree which was recorded as dead during the past remeasurement and whose diameter was recorded at that time.

7.4 Tree Characteristics

Classify and record each tree as follows: living; cut; dead; new tree (previously missed); or ingrowth. If possible, identify and record the origin of individual living trees as planted, seeded, or natural. Identify and record the crown position class of live trees as one of the following: emergent; dominant; codominant; intermediate; overtopped/suppressed; understorey; or, open (see Table A2).

In the Great Lakes-St. Lawrence and Carolinian forests, for all hardwood species identify and enter the live-tree quality class (Table A3).

Identify and record any damage to live trees (physical deformities and wounds, e.g. conks, scars, fork or crook, frost crack, rotten branch, hollow, leaning, dead or broken top) and, if possible, the cause of damage. Also attempt to identify and record any pests or diseases present and the extent of any insect defoliation. Finally, if possible determine and record the cause of death of any tree that has died since the last measurement.

7.5 Tree Height Subsample

The number of height measurements required for each species within the growth plot is determined by its percentage of the total basal area within the growth plot under consideration. The species with the highest proportion of basal area in the growth plot is treated as the primary species, except in plots where this species has less than 40 percent of the total plot basal area. In this latter case where no species has greater than 40 percent of total plot basal area, the species with the highest proportion of total basal area in the plot is treated as a secondary species for height sampling purposes.

When 18 or fewer trees of the primary species (the species dominant by basal area) are present in the growth plot, measure and record the total tree height and height to the base of the live crown of all individuals of that species in the growth plot.

If more than 18 trees of the primary species are present in the growth plot, first randomly select and record the individual tree numbers of eight trees for height sampling, from a sample weighted by basal area for that growth plot. Then divide all tagged trees of the primary species into a minimum of 6 diameter classes. Place the individual trees of the primary species selected by the first method into the appropriate diameter class of trees to be measured for the tree height subsample. Then randomly select other individual trees from each diameter class so that a minimum of 3 trees per diameter class are selected for the tree height subsample. Using the combined sampling list, measure and record the total tree height and the height to the base of the live crown for all primary species trees selected for the tree height subsample.

For the secondary species (second by basal area) in each growth plot, select trees for height measurement according to the following method. When 6 or fewer trees of the secondary species are present, measure and record the total tree height and height to the base of the live crown of all individuals of that species. If more than 6 trees of the secondary species are present in any growth plot, first randomly select and record the individual tree numbers of five trees of that species for height sampling, from a sample weighted by basal area for that growth plot. Then divide all tagged trees of that species into a minimum of 3 diameter classes. Place the individual trees selected using the first method into the appropriate diameter class of trees to be measured for the tree height subsample for that species. Then randomly select other individual trees from each diameter class so that a minimum of 2 trees per diameter class are selected for the tree height subsample for that species. Using the combined sampling list, measure and record the total tree height and height to the base of the live crown for the secondary species trees selected for the tree height subsample.

For any remaining species making up more than 20 percent of the total basal area in a growth plot, select trees for height measurement by the method used for the secondary species. Then measure and record the total tree height and height to the base of the live crown for each selected tree.

For all remaining species constituting less than 20 percent of the total basal area in a growth plot, select at least three trees for height measurement, across the range of diameters for that species. Then measure and record the total tree height and height to the base of the live crown for each selected tree.

Use a height pole for measuring all trees less than 10.0 m high. Use an Abney, clinometer or surveyor's transit for trees higher than 10.0 metres. For trees higher than 10 metres, the azimuth and distance from the tree to where the height measurement is taken must be accurately measured and recorded.

7.6 Tree Height Subsample Marking

For all trees selected and measured for total height and height to the base of the live crown, identify and mark the tree with a small dot of paint just above breast height.

7.7 Crown Closure Description

Estimate to the nearest 5 percent and record the average tree percent crown cover on each growth plot for two tree height classes: greater than 10.0 metres in height; and, less than 10.0 metres in height.

8.0 PARAMETERS TO BE MEASURED - SHRUB PLOTS

8.1 Tall Shrub Sample

In the shrub plots, record the percent ground cover of all shrubs, by genus, in the intermediate (0.5-2.0 m) and tall (2.0-10.0 m) height classes.

9.0 PARAMETERS TO BE MEASURED - REGENERATION PLOTS

9.1 Sapling Subsample

In the regeneration plots, for all living trees less than 2.5 cm in dbh but more than 130 cm high, count and record the number of trees by species.

9.2 Regeneration Subsample

Count and record by species the number of living trees between 50 cm and 130 cm (inclusive) in height in the regeneration plots.

9.3 Seedling Subsample

Record the percent ground cover of individual species in the regeneration plots, for all living tree seedlings less than 50 cm high.

9.4 Low Shrub Subsample

Record by genus the percent ground cover in the regeneration plots of all shrubs in the low shrub height class (0.0-0.49 m).

9.5 Ground Vegetation Subsample

Record the percent ground cover of all ground vegetation in the regeneration plots according to the following groupings: sphagnum mosses; feathermosses; reindeer mosses (cladina spp); other mosses (includes dicranum, polytrichum, and mnium); other lichens and liverworts; ferns and fern allies; grasses; sedges; and herbaceous plants.

10.0 INCREMENT CORE SAMPLING

Choose a sample representative of a cross-section of the diameter distribution of the primary species (dominant by basal area) within the combined growth plot areas. Use an increment borer, count the annual rings and record the breast height age of a minimum of 5 trees in the buffer area, outside the mortality plot boundary and more than 10 m from a growth plot boundary. For all primary species trees sampled in the buffer area for tree age, measure and record the thickness of the bark at breast height, as well as the radial growth increments at breast height for the last 5-, 10- and 15-year periods, to the nearest millimeter.

For each growth plot secondary species, and any other species contributing more than 20 percent of the total basal area in each growth plot, choose a minimum of 2 trees in the buffer area outside the mortality plot boundary and more than 10 m from a growth plot boundary. Extract an increment core from each selected tree and record its breast height age, the thickness of the bark at breast height, as well as the radial growth increments at breast height for the last 5-, 10- and 15-year periods, to the nearest millimeter.

Where no stem analysis is to be carried out in conjunction with the plot (see Section 11, Stem Analysis Sampling), obtain the total ages by using the increment borer at the base of all the trees sampled for breast height age. Also measure and record the total tree height for all the trees sampled for breast height age within the buffer area.

11.0 STEM ANALYSIS SAMPLING

Stem analysis will be used in some plots to obtain information on upper stem diameters, crown width, and height to merchantable limits, but no trees may be cut within the mortality plot or non-destructive sampling buffer area. All stem analysis must be carried out in the destructive sampling buffer area, at least 10 m from the mortality plot boundary.

Where stem analysis is to be carried out in conjunction with PSP measurement, cut down a minimum of 6 trees within or outside the destructive sampling buffer area. The trees have to be well-distributed across the range of diameters of the primary species in the PSP. This can be achieved by taking trees from 6 diameter classes. The individual trees selected for stem

analysis should also have the same diameter/height relationship as the diameter classes within the plot.

Before cutting down the selected trees, take at least four individual measurements of crown width, on the north, east, south and west sides of the tree. Then from each tree felled for stem analysis, cut at least seven cookies for analysis, at the following heights: tree base, one-half distance between tree base and breast height, breast height, one-quarter distance between breast height and total height; one-half distance between breast height and total height; three-quarters distance between breast height and total height; and at 30 percent of the total tree height. If the tree cut down for stem analysis is more than 15 m high, cut an additional cookie at a distance of 2 metres from the top of the tree.

12.0 LITERATURE CITED

Pierpoint, G. and P. Uhlig. 1988. A minimum standard for describing forest sites with a soil pit. Ontario Ministry of Natural Resources, Toronto, Ontario. 16 pp.

Table A3-1. Mortality Condition Codes - Decay Classes

1.	Tree is recently dead. Top is intact. Most fine branching still present. Bark is intact.
2.	Top is intact. Most of the fine branches have dropped. More than 50% of the coarse branches are left. Bark may begin to loosen.
3.	Top is intact. Fewer than 50% of the coarse branches are left. Depending on the species, bark may (eg. white pine) or may not (eg. white birch) have sloughed off.
4.	Top is broken. No coarse branches remain. Bark may or may not have sloughed off. Height at least 6 metres.
5.	Stub. Top repeatedly broken. No coarse branches remain. Bark may or may not have sloughed off. Height less than 6 metres.
6.	Down. Tree died and fell since the last measurement.

Table A3-2. Live-Tree Crown Position Class

Emergent	A tree with its crown extending well above the general level of the crown layer of the stand, receiving full light from above and from the sides. Much larger than neighbouring dominant trees, with a more fully developed crown (eg. white pine extending beyond a hardwood canopy).
Dominant	A tree with its crown extending above the general level of the crown layer of the stand and of neighbouring trees, receiving full light from above and partly from the sides. Larger than the average trees in the stand, and with a fully developed crown.
Co-dominant	A tree with a crown that forms a part of the general level of the crown cover of a stand, receiving full light from above and comparatively little light from the sides. Usually has a medium sized crown. This class is normally used when there are two or more trees of equal size adjacent to one another that form part of the main canopy of the stand.
Intermediate	A shorter tree when compared to its immediate neighbours, but with a crown extending into the crown layer formed by the dominant and codominant neighbouring trees in the stand, receiving direct light from above but not from the sides. Usually has a small crown, crowded on the side.
Overtopped/ suppressed	A tree with its crown entirely below the general level of the crown layer and of its immediate neighbours, receiving no direct light either from above or from the sides. These trees normally have restricted height growth due to competition from neighbouring taller trees, and may exhibit elongated lateral branching.
Understorey	In an even-aged stand, a tree of a clearly much younger age class than the stand as a whole. These trees otherwise would fit in the overtopped/suppressed category, with crowns entirely below the general level of the stand crown layer, receiving no direct light either from above or from the sides. These trees are usually of shade-tolerant or semi shade-tolerant species.
Open	A tree that would have been previously classified as intermediate, overtopped/suppressed, or understorey, but that has been "released" due to stand break-up, windthrow, blowdown etc. This tree is now found in a stand opening, and although it is not as tall as the main canopy layer of the stand, it receives full light from the top and from the sides. Also includes trees that have established themselves in an area not previously occupied by other trees.

Table A3-3. Tolerant Hardwood Quality Classes

A1	Trees that contain or can potentially produce high-quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop tree producers of high quality sawlogs or veneer logs.
A	Trees that have bole quality equal to Class A1 trees, but that are of high risk or are expected to decline within a 20-year period.
B1	Trees that contain or are potentially capable of producing medium-quality logs and that are expected to at least maintain their present quality for a 20-year period. Such trees would normally be considered crop tree producers of sawlogs for dimension lumber.
B	Trees that have bole quality equal to Class B1 trees, but that are of high risk or are expected to decline within a 20-year period.
C	Trees containing or having the potential to produce low-quality logs but no better. Such trees are often used for pulpwood, poker poles, bolter logs, or fuelwood, but are not normally considered crop trees.
D	Cull trees by Crown Timber Act standards: no sawlog potential, but possibly usable for pulpwood or fuelwood if a strong market exists.